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SHALLOW GROUND WATER IN SELECTED AREAS IN THE FORT UNION COAL REGION

Northern Great Plains Resource Program

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SHALLOW GROUND WATER IN SELECTED AREAS IN THE FORT UNION COAL REGION

open-file report 74 48

Helena, Montana

1974

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Three sample areas are analyzed to determine potential pollution impacts of surface mining on the shallow ground water systems. Areas analyzed were in the southeastern portion of North Dakota, the Gillette area of Wyoming and the Decker-Birney area of Montana. They were selected as representative of areas where accelerated coal mining is likely to occur. The analyses indicates there will be: 1) Localized disruptions of aquifers; 2) Drainage of adjoining clinker beds; 3) Drainage of aquifers in immediate vicinity of mines; 4) Underlying aquifers will be little affected; 5) Possible increase in nitrate and sulphate concentrations in mine waters; and most importantly 6) Contamination of the water resource by dissolved material leached from strip-mine spoils. All problems except pollution of ground water from spoils should be minimal after replacement of spoils and rehabilitation. Ground water pollution could be long term.

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SHALLOW GROUND WATER IN SELECTED AREAS IN THE FORT UNION COAL REGION

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of Water Work Group
Northern Great Plains Resource Program

U.S. Geological Survey Open-file Report 74-48

A preliminary appraisal of the
impacts of surface mining on
the shallow ground-water resource

1974

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SHALLOW GROUND WATER IN SELECTED AREAS IN THE FORT UNION COAL REGION

By Ground-water Subgroup of Water Work Group
Northern Great Plains Resource Program

SUMMARY

Ground-water conditions and the possible effects of strip mining on shallow aquifers are considered for three priority areas in the northern Great Plains--the Gascoyne area in North Dakota, the Gillette area in Wyoming, and several subareas within the Birney-Decker area in Montana. Shallow aquifers are defined as those aquifers overlying the Pierre Shale; they include alluvium, sandstone or coal beds in the Wasatch, Fort Union, Lance, and Hell Creek Formations, and the Fox Hills Sandstone.

The Gascoyne area is on the western edge of the Williston Basin. Ground-water movement is generally northeastward toward discharge areas along the Missouri River Valley. Permeability of the lignite beds is not known, but probably is comparable to the average permeability of the sandstone aquifers, which is about 2 feet per day. Major constituents in the water are calcium, magnesium, sodium, bicarbonate, and sulfate. Dissolved solids range from about 1,500 to 2,000 mg/l. Concentrations of calcium and magnesium generally decrease with increasing depth as sodium and bicarbonate become the dominant ions.

The Gillette area is near the eastern edge and the Birney-Decker area is in the north-central part of the Powder River Basin. Ground-water in the deepest of the shallow aquifers--Basal Hell Creek-Fox Hills in Montana or Lance-Fox Hills in Wyoming--flows generally northward and discharges by upward leakage along the Yellowstone River Valley and along the lower reaches of the Tongue River and Powder River Valleys. The direction of ground-water movement in the Fort Union and Wasatch Formations is controlled largely by the local topography. Water enters the system along the interstream divides and moves downward and laterally toward the nearby valleys. Much of the water is discharged by springs, seeps, or wells, but some enters the alluvium along the stream valleys where it augments streamflow or underflow and is eventually largely dissipated by evapotranspiration.

Major constituents in water from bedrock aquifers in both the Gillette and Birney-Decker areas are calcium, magnesium, sodium, bicarbonate, and sulfate. Dissolved solids average about 2,000 mg/l in the Gillette area and about 1,500 to 2,000 mg/l in the Birney-Decker area. As in the Gascoyne area, amounts of calcium and magnesium decrease with depth as the amount of sodium increases.

Strip mining in these areas will involve the removal and interruption of shallow aquifers. Which aquifers will be affected and how far the effects will extend depends largely on the site selected for mining. Mines that penetrate alluvium can be

expected to decrease the amount of ground water in the alluvium and in the adjacent bedrock. The effect may be to degrade the quality and quantity of streamflow. Mines that tap bedrock aquifers in ground-water discharge areas can be expected to lower water levels in nearby wells and springs, but the effect on the quality of the water probably can be contained within the developed area. Mines that tap bedrock aquifers in ground-water recharge areas also can be expected to lower water levels in nearby wells and springs, but special precautions may be needed to prevent contamination of underlying aquifers.

The effects of mining will include: (1) localized disruption of the coal and overlying sandstone aquifers and loss of existing wells in the mined areas; (2) drainage of clinker beds adjacent to the mined area; (3) drainage of the coal and overlying sandstone aquifers in an area around the mine; this effect will be most apparent along the strike of the beds in the immediate vicinity of the mine; (4) underlying aquifers in recharge areas should be little affected, but removal of coal and overburden might cause a small increase in upward leakage from underlying aquifers in discharge areas; (5) blasting and handling of the coal could increase nitrate and sulfate concentrations in mine waters.

The most detrimental effect on the ground-water system may be contamination of the water resource by dissolved materials leached from the excavated overburden or spoils, which are used

for mine backfill. Available data indicate that the leachate may contain several times more dissolved solids than water in the aquifers and also ma, contain harmful concentrations of trace elements, including heavy metals. The problem is complicated by the fact that leaching probably will continue long after mining has ceased. Therefore, studies of rock-water chemical reactions and the direction and movement of leachates are essential to the development of plans to prevent unnecessary contamination of the water resource.

Additional studies are needed to determine: (1) The hydrology of the coal beds and the effect of coal on the quality of water; (2) predevelopment hydrologic conditions at proposed mine or other development sites; (3) how mining or development plans can utilize the natural flow system at those sites to prevent local damage to the ground-water resource; and (4) how regional ground-water systems in the Williston and Powder River Basins will be affected by full-scale mining and consequent development of water supplies.

INTRODUCTION

The Fort Union coal region is in a semiarid area where water availability largely determines the value and possible uses of the land. Coal beds supply many of the springs and wells that are dependable sources of water. Because of the importance of these ground-water supplies, questions concerning the effects of coal development on shallow ground-water supplies began to receive attention in the late 1960's. A principal concern was whether coal development could cause existing wells and springs to "dry up" or "go bad".

By 1970 various public and private organizations had initiated programs to gather and analyze ground-water data. These programs were designed to obtain predevelopment, baseline data and to describe general conditions of ground-water occurrence as the framework from which the consequences of coal development could be predicted. By 1973, in Montana alone, at least 13 public agencies and 4 private organizations were actively supporting or engaged in programs concerning the shallow ground-water resources of the Powder River Basin. While the individual groups were aware of one another's programs, no one group was responsible for coordination of the work efforts.

In November 1973 the Water Work Group Leader of the Northern Great Plains Resource Program met with those agencies

having interest in or responsibility for the shallow ground-water resource. A ground-water subgroup was formed with members from the U.S. Bureau of Land Management, U.S. Bureau of Reclamation, U.S. Environmental Protection Agency, Montana Bureau of Mines and Geology, North Dakota State Water Commission, U.S. Forest Service, U.S. Geological Survey, and Wyoming State Engineer's office. The subgroup is coordinated by the U.S. Geological Survey. Funding is provided primarily by the Northern Great Plains Resource Program and by the Environmental Protection Agency.

Objectives of the ground-water subgroup are to:

1) Coordinate efforts of State and Federal agencies that use or collect ground-water data.

2) Supplement and evaluate existing ground-water data, to identify potentially serious problems, and to recommend studies necessary to provide problem solutions.

3) Collect and compile baseline data and begin a monitoring system to detect changes in water quality and in ground-water levels.

4) Supply preliminary answers to questions posed by the Water Work Group regarding the impact of surface mining on shallow aquifers.

The purpose of this report is to describe briefly the occurrence of ground water in shallow aquifers in selected areas

in the Fort Union coal region, to provide preliminary answers to questions posed by the Water Work Group regarding the impact of surface mining on those aquifers, and to recommend studies necessary to provide solutions to inferred problems.

The following questions were posed by the Water Work Group:

1. Will the water supply from aquifers supporting farm-ranch wells be interrupted? Can deeper drilled wells replace the supplies with water of equivalent quality prior to restoration of mined areas?

2. What is the probable movement of ground water between aquifers underlying the surface at various depths? Is movement upward or downward? Will contamination result from mining? Is it serious? What harm could result? What are the expected limits of influence of mining on ground water?

3. What quantities and qualities of ground-water discharge can be expected from mining? Are the quantities small enough to manage? Is the quality expected to be worse than that presently discharging at the surface? How much difference should be expected between spoil-bank leach water and the normally percolating shallow water?

4. After backfilling and reclaiming of mined areas is completed, will water levels in shallow wells return to near the original levels?

5. Can evaporation ponds for leach waters and solid wastes be lined successfully to prevent ground-water deterioration because of contamination by leachates?

To provide answers in the time allotted, data collection and interpretation were necessarily confined to three priority areas in the Fort Union coal region (fig. 1). They include the Gascoyne area in southwestern North Dakota, the Gillette area in northeastern Wyoming, and several subareas within the Birney-Decker area in southeastern Montana. These areas were selected for study primarily because their coal deposits probably will be among the first to be developed. Results of these studies will be used to formulate plans and recommendations for further studies and for monitoring the ground-water resource in these and other areas in the coal region.

Preliminary tables of basic data listing field measurements made in the priority areas are included in this report. Data from other studies in Montana are being compiled. These data will be available from the District Chief, U.S. Geological Survey, Helena, Montana, or the State Geologist, Montana Bureau of Mines and Geology, Butte, Montana. A monitoring program consisting of test drilling, water-level measurements, chemical analyses of water samples, and specific conductance measurements of ground water in mine spoil piles and backfill materials will begin by July 1974.

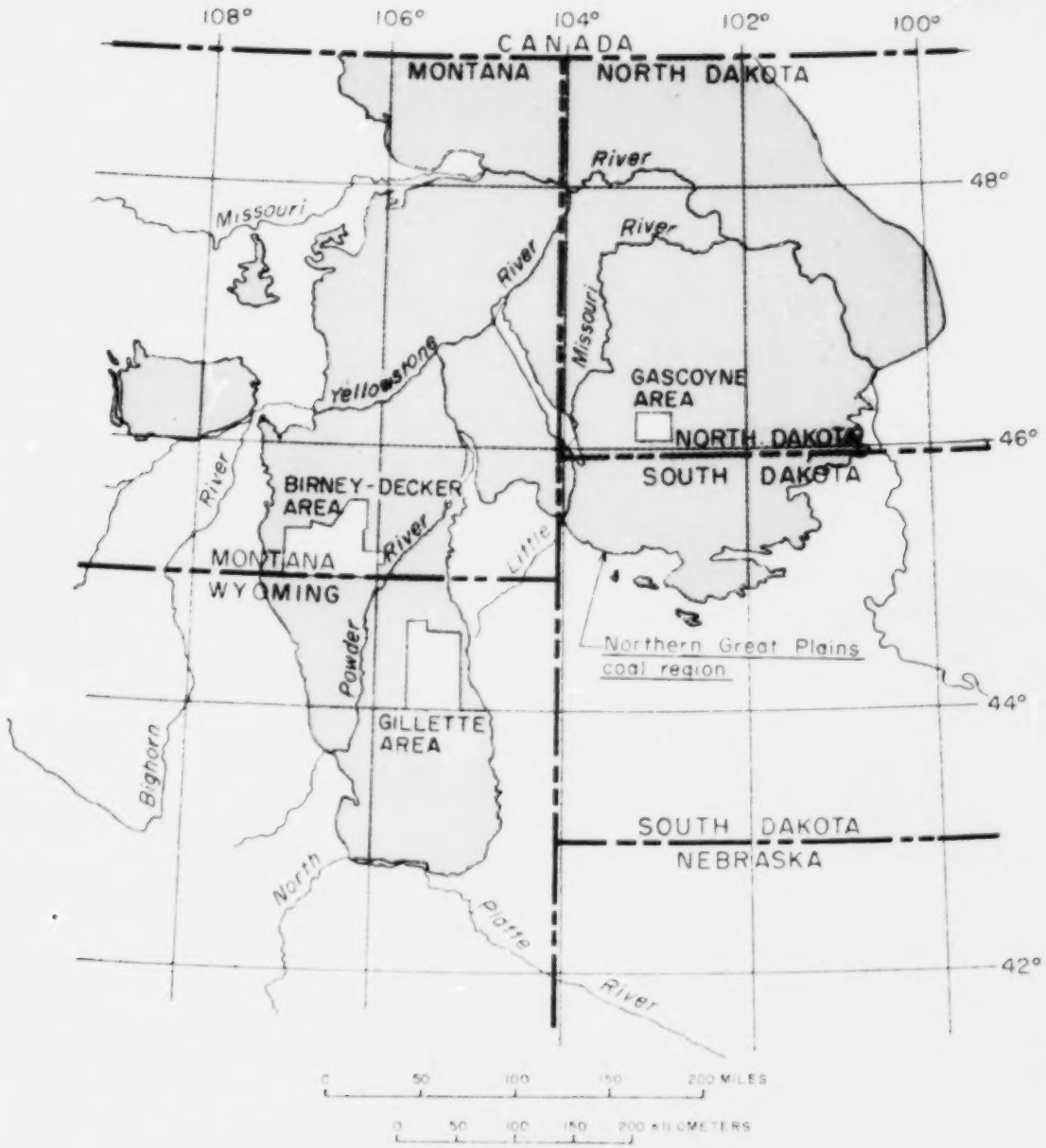

Figure 1.—Location of northern Great Plains coal region and study areas. (Modified from Rocky Mountain Association of Geologists, 1972.)

For those readers interested in using the metric system, metric equivalents of English units of measurements are given in parentheses. The following factors for converting English units used in this report to metric units are shown to four significant figures. However, where values discussed are only approximate, the metric equivalents are rounded to numbers consistent with the English units.

From		Multiply by	To obtain	
Unit	Abbreviation		Unit	Abbreviation
inch	in	25.40	millimeter	mm
foot	ft	0.3048	meter	m
mile	mi	1.609	kilometer	km
square mile	mi^2	2.590	square kilometer	km^2
cubic foot per second				
	ft^3/s	28.32	liters per second	l/s
		28.32	cubic decimeter per second	dm^3/s
		0.02832	cubic meter per second	m^3/s
foot per mile	ft/mi	0.3048/1.609	meter per kilometer	m/km
acre-foot	ac-ft	1233	cubic meter	m^3
		1.233×10^{-3}	cubic hectometer	hm^3
ton (short)	ton	0.9072	metric ton (tonne)	t

Acknowledgments

Many of the data used in this report were collected for areal ground-water investigations by the U.S. Geological Survey in cooperation with the Montana Bureau of Mines and Geology, the Montana Department of Natural Resources and Conservation, the North Dakota State Water Commission, and the Wyoming State Engineer. Studies by the university systems in all three States were used to help develop concepts and supply data. Land owners and mining companies granted access to their property and permission to collect hydrologic data. Without the help of these many individuals, this report would not be possible.

Previous investigations

A number of reports describing the geology and mineral resources of the northern Great Plains were useful in this study. The earliest ground-water studies in the Powder River Basin include those by Perry (1931 and 1935) and Renick (1929) in Montana, that by Simpson (1929) in North Dakota, and that by Darton (1905) in Wyoming. More recent studies in Montana include Taylor (1968), Miller (1969), and Hopkins (1973). Trapp (1971) reported on the results of test drilling and well inventory in Stark and Hettinger Counties, North Dakota. Croft (1973) described the ground-water conditions in Mercer and Oliver Counties, North Dakota. Recent studies in Wyoming include Whitcomb, Cummings, and McCullough (1966), Lowry and Cummings (1966), and Crist and Lowry (1972). Reports by King and by Hodson and others are in press.

Location-numbering system

The locations of wells or other features are designated by a numbering system based on the Federal system of land subdivision, which locates a tract of land with respect to the principal meridian and base line for a State. Locations in North Dakota and Wyoming are north and west of the principal meridian and the base line that are used for these two States. Locations in Montana may be north or south of the Montana base line and are east of the principal meridian for that State.

The first number denotes the township and the second number denotes the range. (For locations in the Powder River Basin in Montana, for example, the letters N or S follow the first number, and the letter E follows the second number. These letters show whether the location is north or south of the base line and that it is east of the principal meridian.) The third number denotes the section and is followed by one or more letters showing the location of a feature within the section. This is accomplished by subdividing the section into quarters, lettered A, B, C, and D in a counterclockwise direction, beginning in the northeast quarter. Similarly, each quarter may be further divided into quarters, each lettered as before (fig. 2). For example, a well in Montana might be numbered 03S45E15DDD, which indicates that the well is in the SE¼ of the SE¼ of the SE¼ of section 15, T. 3 S., R. 45 E.

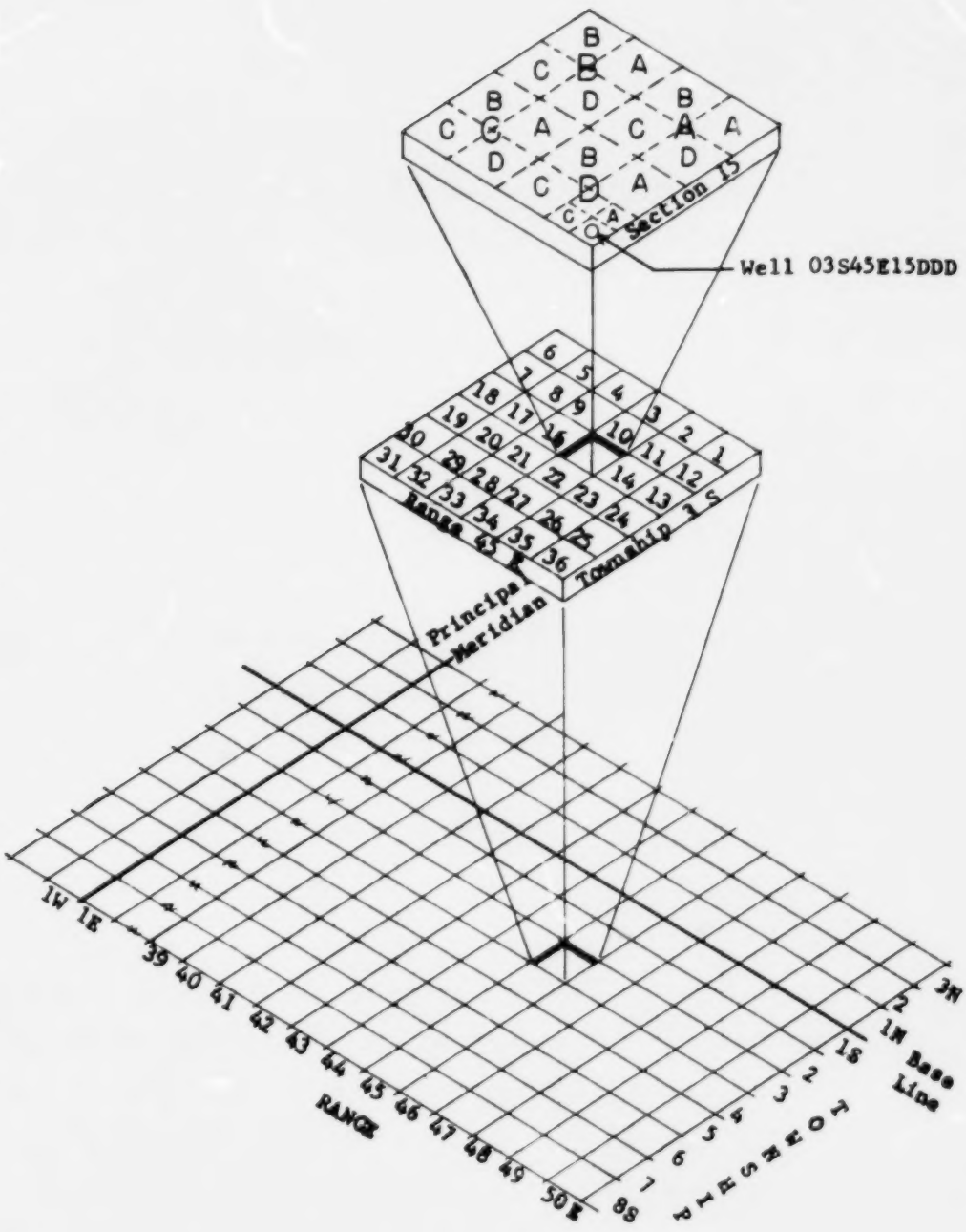

Figure 2.--System for identifying locations.

REGIONAL DESCRIPTION

The northern Great Plains coal region is in the Williston and Powder River Basins. These structural basins (fig. 3, in pocket) are separated from each other by the Black Hills uplift and the Cedar Creek anticline. The Powder River structural basin contains all or parts of several river basins. These include the Tongue, Powder, Little Big Horn, Belle Fourche, Cheyenne, Little Missouri, and North Platte drainage basins. The Williston Basin includes parts of the Little Missouri, lower Yellowstone, and Missouri River drainage basins.

The structural basins have been filled with several thousand feet of sedimentary rocks. Of importance to this report are the rocks that overlie the Pierre Shale which, because of its relatively low permeability and great thickness, separates the overlying shallow aquifers from the underlying deeper aquifers. The lithologic and water-bearing characteristics of formations above the Pierre Shale are summarized in tables 1, 2, and 3 (in pocket).

Those aquifers that are younger than the Pierre Shale do not extend across the Black Hills uplift or the Cedar Creek anticline. Thus, the ground-water flow systems in the shallow aquifers are separate in each basin. Although the flow systems are complex in detail, simplified sections across the regional flow systems are depicted in figures 4 and 5.

Ground-water movement in the southwestern part of the Williston Basin is from the recharge area in the Bowman-Gascoyne area

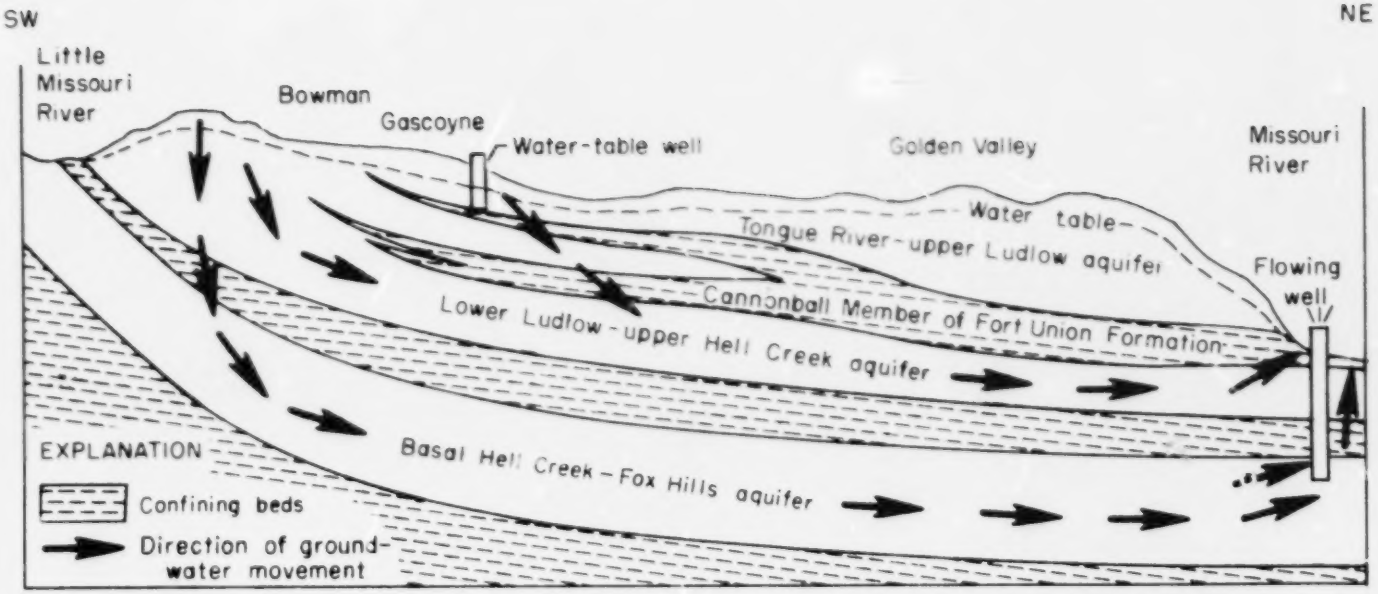

Figure 4.—Hypothetical hydrologic section from Little Missouri River northeastward through Gascoyne to the Missouri River, North Dakota.

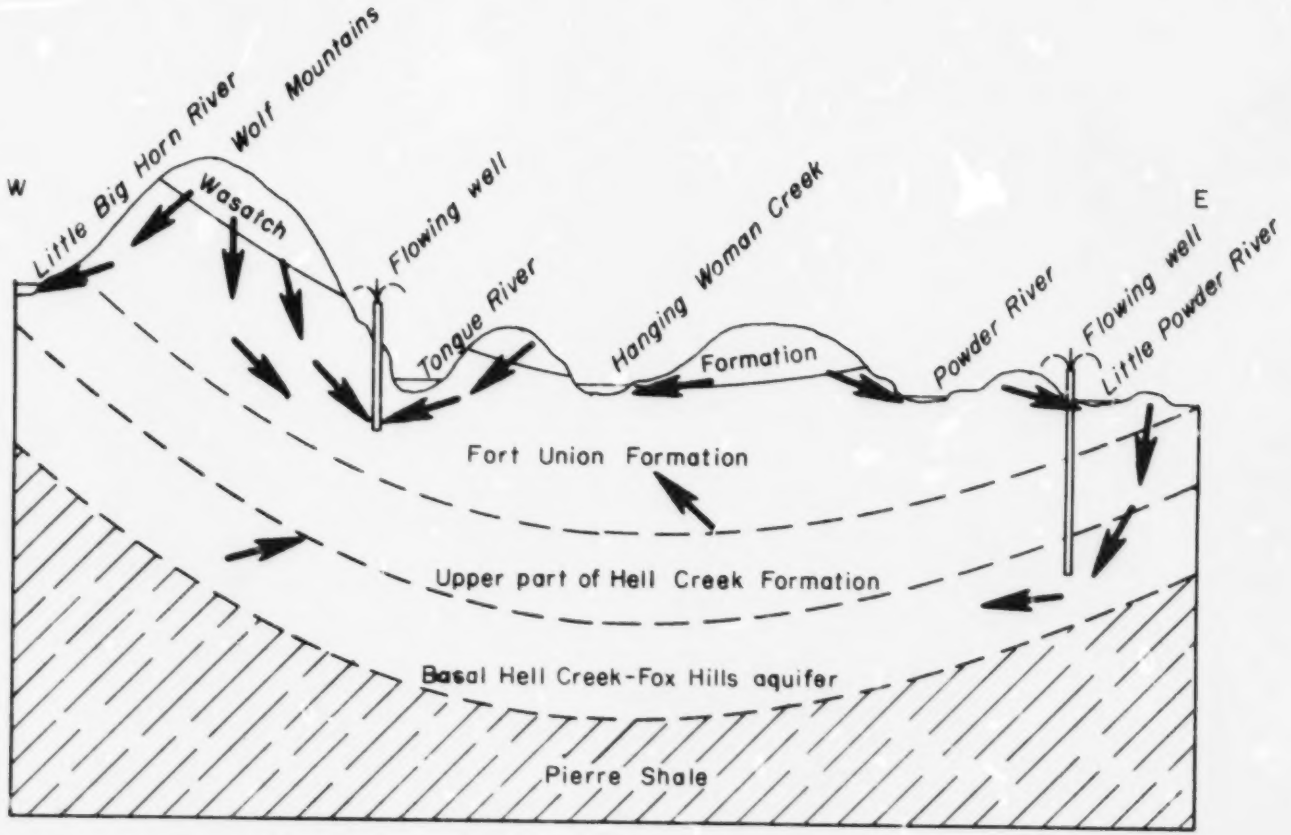

Figure 5.– Hypothetical sketch across the northern part of the Powder River Basin. Arrows indicate direction of ground-water movement.

northeastward toward the Missouri River. Potentiometric head in the recharge area decreases with depth. Wells that tap Paleocene and Upper Cretaceous aquifers generally have progressively lower water levels with increasing depth. In the discharge area along the Missouri River Valley, potentiometric head increases with depth. Wells that tap these aquifers flow at the land surface (Croft, 1973).

In the Powder River Basin ground-water movement in the shallow aquifers (those above the Pierre Shale) is determined largely by the topography and structural configuration of the basin. Movement in the deepest of these shallow aquifers--Basal Hell Creek-Fox Hills in Montana or Lance-Fox Hills in Wyoming, generally referred to collectively in both areas as the Fox Hills aquifer--has been defined for part of the basin by earlier studies (Lowry and Miller, written commun., 1974).

The Fox Hills aquifer crops out along the Bighorn and Black Hills uplifts. Ground-water recharge occurs in the outcrop areas and also by downward leakage from overlying rocks in the central part of the basin. Water apparently moves from the higher outcrop areas toward the lower elevations in the northern and probably the southeastern parts of the basin. The location of the ground-water divide between the ground-water movement northward toward the Yellowstone River and southward toward the North Platte River is not known, but it must be south of Gillette. Data indicate that most of the discharge in the northern part of the basin occurs primarily by upward leakage through the overlying rocks in areas

along the Yellowstone River Valley and along the lower reaches of the Tongue River and Powder River Valleys.

The direction of ground-water movement in the Fort Union and Wasatch Formations, which are deeply incised by streams, is influenced strongly by the local topography. Water that enters the aquifers in the topographically high areas along the interstream divides moves downward and laterally toward the nearby valleys. Much of the water is discharged by springs, seeps, or wells, but part of the water is discharged to the alluvium along the streams where it augments streamflow or is dissipated by evapotranspiration.

The climate in the Powder River Basin and in the western part of the Williston Basin is semiarid and continental. Characteristics include abundant sunshine, low relative humidity, generally low precipitation (confined largely to the warmer part of the year), moderate wind, large diurnal temperature variations, and pronounced seasonal extremes of temperature.

AREA DESCRIPTIONS

Gascoyne area

Hydrogeologic setting

The Gascoyne area lies in the unglaciated area of the Missouri Plateau (Fenneman, 1946). It includes about 220 square miles (570 km^2) of Adams and Bowman Counties in southwestern North Dakota (fig. 6, in pocket). The rolling grassed uplands have a maximum altitude of about 3,150 feet (960 m) on Whetstone Butte about 10 miles (16 km) north of Reeder. Maximum relief is about 250 feet (76 m). The principal streams, Cedar and Buffalo Creeks, drain generally southeastward and are tributary to the Missouri River.

Coal mining and agriculture are the chief economic activities in the Gascoyne area. The Gascoyne (Peerless) mine currently (1973) produces about 100,000 tons (90,700 t) of lignite per year by surface-mining methods. Operations are being expanded, however, to mine about 3,000,000 tons (2,700,000 t) per year.

Sedimentary rocks in the Gascoyne area have an aggregate thickness of about 12,000 feet (3,700 m). Most of the usable ground water, however, is pumped from rocks younger than the Pierre Shale (table 1). The Pierre Shale is a dark-gray to brownish-black fissile shale about 1,700 to 2,500 feet (520 to 760 m) thick that yields little or no water to wells. Thus, for practical purposes it forms the base of the shallow ground-water reservoir and is an excellent stratigraphic marker. Rocks overlying the Pierre Shale include in ascending order the Fox Hills Sandstone, Hell Creek Formation, and Fort Union Formation. These younger rocks have a maximum combined thickness of about 1,400 feet (430 m)(table 2).

The Fox Hills Sandstone consists of interbedded marine, grayish-white to brown glauconitic sandstone and greenish-gray shale. The Hell Creek Formation consists of continental dark-gray and brown lenticular sandstone and claystone; it is tentatively divided into three units for purposes of this study (table 2). The upper unit is predominantly sandstone and siltstone and generally yields water to wells. The middle unit is characteristically fine grained and is not an aquifer. The lower unit is similar to the upper unit and, together with sandstone in the upper part of the underlying Fox Hills Sandstone, is collectively referred to as Basal Hell Creek-Fox Hills aquifer or as the Fox Hills aquifer. The Fort Union Formation consists of sandstone interbedded with siltstone, claystone, and lignite. It is about 700 feet (210 m) thick and has been divided in ascending order into the Ludlow, Cannonball, and Tongue River Members. The Ludlow Member consists of interbedded continental sandstone, siltstone, claystone, and lignite. The Cannonball Member is the marine equivalent of the Ludlow Member and can be easily recognized in well logs. The Tongue River Member consists of massive gray to tan sandstone, siltstone, shale, and lignite. The stratigraphic sequence in the Gascoyne area is complicated by intertonguing of these members (fig. 7, in pocket). Beds dip northeastward about 20 feet per mile (4 m/km).

The lithology, thickness, water-bearing characteristics of shallow aquifers in the Gascoyne area, and the quality of water obtained from them are described in table 2. Of importance to

this study is that fractured lignite beds in the Tongue River-upper Ludlow aquifer are highly transmissive and conduct large quantities of water. The most important of these beds, which supply water to domestic, livestock, and public-supply wells in the area, is the Harmon lignite bed near the base of the Tongue River Member of Fort Union Formation (Kepferle and Culbertson, 1955). This bed is 10 to 32 feet (3 to 9.8 m) thick, underlies about 10.4 square miles (26.9 km^2), and is estimated to contain about 273 million tons (248 million t) of lignite. Overburden about 30 feet (9 m) thick is being removed to expose this bed at the Gascoyne mine. The lower part of the lignite is below the water table and must be drained before it can be mined.

The Tongue River-upper Ludlow aquifer increases in thickness from about 60 feet (18 m) to about 260 feet (80 m) from the southwest to the northeast corner of the area. The water table is essentially flat in the vicinity of the Gascoyne mine. In the northeastern part of the area, however, the hydraulic gradient is northeastward about 30 feet per mile (6 m/km). Moreover, the head in this aquifer is 75 to 100 feet (23 to 30 m) higher than the head in the underlying aquifer. The Gascoyne mine, therefore, is in a recharge area near the ground-water divide. To the north, ground-water movement is generally northeastward toward the discharge area along the Missouri River Valley. South of the mine, movement is generally southeastward toward Buffalo Creek.

Approximately 185 acre-feet (228,000 m^3) of water from rivers, streams, and ground-water reservoirs was used in the Gascoyne area

in 1972. Municipal and domestic water supplies, which are obtained wholly from wells, totaled about 50 acre-feet (62,000 m^3). The cities of Scranton and Reeder pumped about 47.4 acre-feet (58,400 m^3) from the Fox Hills aquifer. Total pumpage from other aquifers by rural residents is estimated to be about 2.6 acre-feet (3,200 m^3). Estimates from data collected by the U.S. Bureau of the Census (1969) and Murray (1968) indicate that livestock in the area used about 135 acre-feet (166,000 m^3) of water. About 1,500 acre-feet (1.8 hm^3) was pumped from the Gascoyne lignite mine into Buffalo Creek; this water was not used in the area.

Water samples from 28 wells in the Gascoyne area indicate that water in the Tongue River-upper Ludlow aquifer is generally a sodium sulfate to sodium bicarbonate type, although calcium and magnesium are major constituents in some water samples. Sulfate constitutes as much as 61 percent of the anions in some samples. Dissolved solids range from about 650 to 2,000 mg/l. Water in the deeper aquifers is generally a sodium bicarbonate type. Presumably, calcium and magnesium are replaced with sodium by cation exchange as the water percolates downward through the rocks. Chloride constitutes as much as 21 percent of the anions in the Fox Hills aquifer, but generally less than 5 percent of the anions in the overlying aquifers. Dissolved solids range from about 1,000 to 1,600 mg/l. Water from aquifers above the Fox Hills generally is colored various shades of brown by soluble organic compounds.

Figure 8 illustrates the change in dissolved solids with depth. Although the scatter is marked, water from the deep wells

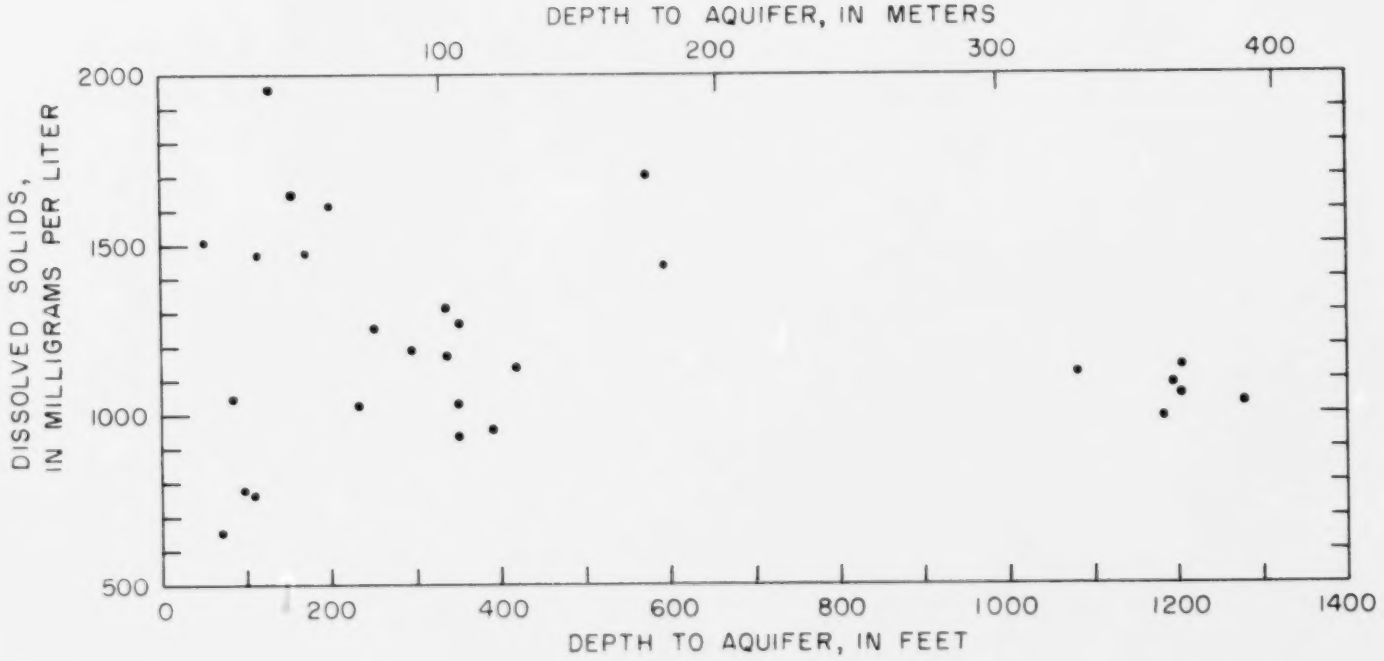

Figure 8.-Dissolved solids versus depth to aquifer, Gascoyne area, North Dakota

generally has less dissolved solids and a smaller range of dissolved solids than water from the shallower aquifers. Ion exchange and other sorptive processes may be involved in the apparent change in water chemistry with depth, but further work will be necessary to define the mechanisms responsible.

Effects of surface mining

When dewatering at the mine ceases, water levels in the aquifer should recover to approximately the original level probably in less than 10 years. Initially, spoil materials used for backfill as mining progresses probably will have greater porosity than the undisturbed overburden and equal or greater permeability in the vertical direction than in the horizontal direction. Lateral permeability should be significantly reduced by mixing sandstone and claystone during backfilling operations. Very probably, however, the porosity and permeability of the backfill materials will decline progressively as the materials compact with time.

Although water samples from wells tapping the Tongue River-upper Ludlow aquifer near the Gascoyne mine contain 643 to 1,950 mg/l dissolved solids, water pumped from the mine generally approximates the higher value, and is approximately equivalent to the quality of base flow in nearby streams. Sandoval and others (1973, p. 12) injected distilled water into samples obtained from spoil-bank materials. The water extracted was generally a sodium sulfate type; specific conductance ranged from 3,000 to 8,000 micromhos per centimeter at 25°C. Water similarly extracted from two topsoil

samples was a calcium bicarbonate-calcium sulfate type and had a specific conductance of less than 1,000 micromhos. A water sample collected by Fred Sandoval (oral commun., Feb. 26, 1974) from a lake in the bottom of the Gascoyne mine had a specific conductance of 4,300 micromhos. These data suggest that the leachate from spoil materials at the Gascoyne mine percolates downward in the mine area and mixes with water in the aquifer. Thus, water pumped from the mine probably will contain a higher concentration of dissolved solids than that normally found in water pumped from the Tongue River-upper Ludlow aquifer elsewhere in the area.

When dewatering ceases, leachate from the spoil materials will continue to percolate downward and mix with water in the aquifer. Ground-water movement then will be down gradient, northeastward or southeastward from the mine. The underlying aquifers are protected from direct contamination by the relatively impervious Cannonball Member of the Fort Union Formation and by confining beds in the Hell Creek Formation. The concentration of dissolved constituents in water percolating through these confining beds possibly may be lowered by sorptive reactions with these fine-grained materials. Other chemical change may take place through bacterial action.

Evaporation ponds for leach water or pits for solid waste could be constructed about 3 miles southeast of the mined area where the surface is underlain by the relatively impervious Cannonball Member of the Fort Union Formation (fig. 6). This

procedure would assure minimal contamination of the ground-water recource as a consequence of vertical and/or horizontal seepage from these ponds or pits. Otherwise, it probably will be necessary to provide an impermeable lining in the pits to prevent contamination of the Tongue River-upper Ludlow aquifer.

Gillette area

Hydrogeologic setting

The town of Gillette lies in the west-central part of the study area (fig. 11), near the east-trending drainage divide between the Little Powder River to the north and the Belle Fourche River to the south. Donkey Creek, a tributary to the Belle Fourche River, heads on the divide west of Gillette and flows generally eastward across the central part of the area at a gradient of about 10 to 15 feet per mile (1.9 to 2.8 m/km). The area south of the Donkey Creek watershed drains generally to Caballo Creek. Caballo Creek in turn flows eastward at a gradient of about 10 to 15 feet per mile (1.9 to 2.8 m/km) to its junction with the northeast flowing Belle Fourche River, which crosses the southeast corner of the area. Streams draining the area north of the Donkey Creek watershed flow generally northward to the Little Powder River at a gradient of 25 to 30 feet per mile (4.7 to 5.7 m/km).

Rocks comprising the shallow aquifers in the Gillette areas include five bedrock units--the Fox Hills Sandstone and Lance

Formation of Upper Cretaceous age, the Tullock and Lebo Shale Members of the Fort Union Formation of Paleocene age, and the Wasatch Formation of Eocene age. In addition, stream valleys are underlain by unconsolidated alluvial deposits of Holocene age. The outcrop areas of the bedrock units are shown on figure 9 (in pocket). The outcrop pattern of the alluvium, however, has not been mapped.

The Fox Hills Sandstone is predominantly fine- to medium-grained sandstone about 150 feet (46 m) thick. It is an aquifer throughout the Gillette area. Industrial wells near Rozet yield about 0.5 ft^3/s (14 l/s). Water from this aquifer generally contains 500 to 1,000 mg/l dissolved solids, but may contain as much as 3,000 mg/l. Dominant ions are sodium and bicarbonate.

The Lance Formation consists of about 50 feet (150 m) of interbedded shale, sandy shale, and sandstone. Although individual sandstone beds have limited areal extent, they are moderately permeable and sufficient in number that the formation as a whole is considered to be an aquifer. Yields of as much as 0.5 ft^3/s (14 l/s) possibly can be obtained from properly constructed and adequately developed wells in the Lance, but well spacing would be critical because of pumping interference between wells. Water from this formation generally contains 500 to 1,500 mg/l dissolved solids. No single water type is dominant.

Artesian conditions exist in both the Fox Hills Sandstone and the Lance Formation in the Gillette area. Most wells penetrating these rocks in the Gillette area are perforated for both

aquifers and many also tap artesian aquifers in the lower part of the Fort Union Formation. A generalized map of levels in wells finished in these formations (fig. 10, in pocket) shows generally a northward gradient of about 15 feet per mile (2.8 m/km). Recharge to these formations is occurring along their outcrop areas east of the Gillette area (fig. 9) and by downward percolation of ground water in the east-central part of the Powder River Basin. Downward movement is occurring because ground-water levels in shallow overlying aquifers are several hundred feet higher than the water levels depicted on figure 10.

The Tongue River and Lebo Shale Members of the Fort Union Formation and the Wasatch Formation are generally similar in lithology and water-bearing characteristics. These rock units have a total thickness of about 3,000 feet (910 m). All are composed largely of interbedded sandstone, siltstone, mudstone, and shale. All contain coal beds. Thick coal beds of broad areal extent, however, occur only in the upper part of the Lebo Shale Member and in the Wasatch Formation.

Sandstone beds and lenses yield water to wells when they are penetrated below the local level of saturation. In contrast, the encompassing fine-grained rocks are relatively impermeable and yield little or no water to a well. Because of the erratic distribution of sandstone in the Fort Union and Wasatch Formations, the depth to a sandstone aquifer is locally unpredictable. Wells less than a mile apart commonly differ appreciably in depth and type of materials penetrated and yield water of different quality.

Coal beds in this area are generally fractured and are aquifers where they lie below the top of the saturated zone. The occurrence of ground water in thin coal beds of limited areal extent is probably similar to that in sandstone beds and lenses in this area. Thick coal beds of broad areal extent, such as the Anderson bed, which ranges from 5 to 125 feet (1.5 to 38 m) thick, are predictable aquifers characterized by yields of 0.02 to 0.2 ft^3/s (0.6 to 6 l/s) and by only small changes in the gross quality of the water from one well to another.

Yields of as much as 2 ft^3/s (57 l/s) are possible from properly constructed and adequately developed wells in both the Fort Union and Wasatch Formations. Dissolved solids in water from these rock units ranges from about 150 to about 3,500 mg/l The best quality water--generally less than 500 mg/l--is obtained from clinker beds. The poorest quality water generally is obtained from shallow aquifers in the Wasatch Formation. Water from coal beds generally contains 1,000 to 2,000 mg/l dissolved solids.

Although water from the Fort Union and Wasatch Formations is not characterized by a dominant water type, available data suggest that, except for the clinker beds, the very shallow aquifers generally yield a calcium and/or magnesium sulfate water. As depth to the aquifer increases, calcium and magnesium ions give way to sodium ions and sulfate is at least partially replaced by bicarbonate ions. The deeper wells generally yield a sodium bicarbonate water. This general pattern of water quality has been complicated, however, by leakage among aquifers owing to poor well completion

techniques and to corrosion of the casing in old wells where water of poor quality was initially cased off (King, 1974, and N. J. King, oral commun., 1974).

Alluvial aquifers underlie most stream valleys in the area. Deposits range from a few feet in width and depth in small valleys near the drainage divides to as much as a mile (1.6 km) wide and 100 feet (30 m) deep along the lower reaches of the Belle Fourche River. Generally, the thickness is less than 60 feet (18 m). Although generally fine grained, the alluvium underlying the valleys of all perennial and most of the larger ephemeral streams in the area contains permeable lenses and stringers that readily yield water to shallow wells. Yields of about 1 ft^3/s (28 l/s) are possible from properly constructed and adequately developed wells in the larger stream valleys. Water from the alluvium is characteristically hard; dissolved solids concentration ranges from about 500 to as much as 4,000 mg/l, but generally ranges from 1,000 to 2,000 mg/l. Dominant ions are generally calcium, magnesium, and sulfate.

Geologic structure in Tertiary rocks is comparatively simple; formations strike generally northward. South of Gillette, dips average 50 to 75 feet per mile (9.5 to 14 m/km) westward. North of Gillette, dips average 40 to 50 feet per mile (7.5 to 9.5 m/km) westward. This simple structure, however, has a pronounced effect on the movement of ground water.

In the southern half of the Gillette area the dip of the beds is westward in the opposite direction to the slope of the land surface. The westward-tilted, discontinuous aquifers, therefore, tend to fill to the level of the lowest point of outcrop, in the

bottom of the eastward sloping channel of Caballo Creek or the northeastward-flowing Belle Fourche River. The result is that the top of the saturated zone in the southern part of the area slopes generally eastward conforming closely to the slope of the drainage net. The underlying materials are saturated nearly to the surface along the Belle Fourche River and within 10 feet (3 m) of the surface along most of the length of Caballo Creek, but the saturated zone is more than a hundred feet (30 m) deep along the high interstream divides.

Because of the limited opportunity for ground-water recharge along the rugged interstream areas, the slope of the top of the saturated zone away from the divides toward the adjacent valley bottoms depends largely on the permeability and continuity of the shallow aquifers. If the aquifers are permeable and continuous, the slope is generally about 10 to 25 feet per mile (2 to 4.7 m/km). If the aquifers have low permeability and/or are discontinuous, the slope may exceed 100 feet per mile (19 m/km). Thus, the spacing of the contours on the water-level map (fig. 11, in pocket) provides some indication of the permeability and the continuity of the shallow aquifers.

In the northern half of the area the slope of the land surface is generally northward in the direction of strike, which greatly enhances the opportunity for drainage of those aquifers that have appreciable lateral continuity. As a result, the slope of the top of the zone of saturation in the northern two-thirds of the area is generally northward toward points of discharge along

the lower reaches of the Little Powder River, Wildcat Creek, and Cottonwood Creek. An inferred ancient buried channel extends northeastward from the Gillette Municipal Airport, following approximately Wyoming Highway 59. Apparently this channel truncates the full thickness of the Anderson coal bed. The fine-grained materials that fill this inferred channel, which is about a mile wide, apparently retard the northward movement of ground-water in the Anderson bed. As a result, the coal is saturated upslope southeast of the barrier to the level where the bed crosses the Dry Fork of the Little Powder River. Springs discharging from near the base of the coal in this valley reach have an aggregate flow of 0.5 to 1.0 ft^3/s (14 to 28 l/s). In the absence of this underground barrier the Anderson bed would probably be drained throughout much of the area north of Donkey Creek.

Most of the Gillette area is a recharge area, and wells in the Wasatch and Fort Union Formations show decreasing head (lower static water levels) with increasing depth. Ground-water levels are highest along the high, north-trending drainage divide that separates runoff westward to the Powder River from runoff eastward to the Little Powder and Belle Fourche Rivers. Ground-water movement from this high divide, which corresponds approximately to the west margin of the Gillette area, is generally toward the principal river valleys in the direction of the slope of the land surface. Ground-water discharge is occurring in the areas shown on figure 11.

Data from approximately 390 wells were used to prepare the water-level map (fig. 11). Although an effort was made to obtain data from water sources spaced uniformly across the area, it was found that some areas had many wells, others had few or none. Most wells were completed in the Wasatch Formation and comparatively few wells were completed in the Lebo Shale and Tullock Members of the Fort Union Formation. Therefore, only about half of the existing wells in the Wasatch Formation were measured; about 75 percent of the wells in the Tullock Member were measured; and a considerable effort was made to measure all existing wells in the Lebo Shale Member.

About 30 percent of all wells measured in the Gillette area are less than 100 feet (30.5 m) deep; 74 percent are less than 200 feet (61 m) deep; and 91 percent are less than 300 feet (91.5 m) deep. Of these wells, 39 percent have static water levels less than 50 feet (15.2 m) below the surface, 73 percent have water levels less than 100 feet (30.5 m) deep, and 94 percent have water levels less than 200 feet (61 m) deep.

Most wells obtain water from sandstone beds or lenses erratically distributed in the predominantly shale matrix of the Fort Union and Wasatch Formations. Comparatively few wells obtain water from coal beds. The reason appears to be that wells apparently were completed in the first aquifer that yielded suitable water. Because of the westward dip of the coal beds and the eastward slope of the land surface throughout a large part of the Gillette area, the depth to the coal generally increases rapidly westward from the coal outcrop area. Thus, wells in and along the west side

of the coal outcrop generally tap the coal aquifer. Wells a mile or more west of the coal outcrop generally obtain water from overlying discontinuous sandstone aquifers.

The largest springs in the Gillette area discharge from the Anderson coal bed where it crosses the Dry Fork Little Powder River upstream from the buried erosional channel that apparently cut through this bed. These springs have a combined flow of about 0.5 to 1 ft^3/s (14 to 28 l/s) and yield water that has a specific conductance of 1,525 micromhos.

All other springs observed in the area flow less than 0.02 ft^3/s (0.6 l/s). All issue either from coal beds or from near the base of clinker deposits. Springs that issue from coal beds generally occur along drainage courses where the saturated zone intersects the surface. Springs discharging from clinker generally occur on steep slopes or at the base of rubble deposits and reflect perched ground-water conditions with very local recharge. Their importance as a ground-water resource lies mainly in the good quality of the water. Water of springs issuing from clinker generally contains less than 350 mg/l and seldom exceeds 500 mg/l dissolved solids.

Effects of surface mining

The coal and overlying sandstone aquifers will be removed and thus interrupted in the mined areas. Also, wells in the mined areas will be destroyed. Subsequent backfill with excavated overburden as a mine is extended laterally will leave behind a poorly-sorted mass of rock rubble. This rubble, although porous, may be relatively impervious because of poor interconnection among openings.

The exception may occur near the base of the backfill where boulders and wasted coal normally accumulate to form a coarse rubble that is generally highly permeable.

After mining is completed, natural compaction of the backfill will progress with time as the level of saturation in the mined area returns to approximately the pre-mining level. Wells drilled in mined areas after rehabilitation, therefore, probably will obtain water principally from the coarse rubble at the bottom of the backfill or from undisturbed aquifers underlying the excavated coal bed.

As surface mining is extended down dip, the water level in the coal will be lowered progressively in the vicinity of a mine. The water level at the mine will be determined essentially by the intake level of pumps in the bottom of the mine, because ground-water discharge to the mine will probably be less than 1 ft^3/s (28 l/s). The configuration of the water level with increasing distance from a mine will depend largely on the permeability, continuity, and recharge relationships of aquifers within these rock units.

The water-level map (fig. 11) shows that all potential mine areas are in ground-water recharge areas. The vertical component of ground-water movement, therefore, is downward and the horizontal component is generally northward or eastward toward points of ground-water discharge along the lower reaches of Wildcat Creek, the Little Powder River, Cottonwood Creek, and the Belle Fourche River. Downward movement of ground water is small, however, owing to the low permeability (especially vertical permeability) of

shales in the Wasatch and Fort Union Formations. Bedrock aquifers are filled, therefore, to the lowest level where they crop out in the stream valleys. Moreover, these aquifers are discharging sufficient water to maintain a near-surface level of saturation in the alluvium along the larger stream valleys. Although data are meager from which to estimate the discharge from the coal and from the overlying interrupted sandstone aquifers in the proposed mine areas, the amount should present no serious problem to mining operations.

Ground-water discharge to the Wyodak and Amax mines is less than 1 ft^3/s (28 1/s). The combined flow of springs discharging from the Anderson coal bed to the Dry Fork Little Powder River in the reach immediately upstream from the inferred ancient buried channel that apparently interrupts the continuity of the coal in this area is 0.5 to 1 ft^3/s (14 to 28 1/s). It is unlikely, therefore, that ground-water discharge in any of the proposed mine areas will greatly exceed 1 ft^3/s (28 1/s). As more mines are developed in the area, the discharge into individual mines should diminish accordingly.

Because movement of water in the proposed mine areas is primarily updip toward the outcrop areas of the aquifers, the effect of mining will be essentially a lowering of the point of discharge of the coal aquifer to the intake level of the pumps in the bottom of the mine. Points of discharge of interrupted overlying sandstone aquifers will be lowered to the lowest level where they are exposed in the walls of the mine. Recharge to

and direction of ground-water movement in the coal and overlying aquifers, therefore, should be little affected by mining except laterally along strike where aquifers may be largely drained in the vicinity of a mine. Because of the westward dip of strata at 40 to 75 feet per mile (7.5 to 14.2 m/km) and in many localities the eastward slope of the potentiometric surface of the water in the coal and overlying sandstone aquifers, the saturated thickness of these aquifers should rapidly increase westward from mined areas. Mining, therefore, should have these effects: (1) disruption of the coal and overlying sandstone aquifers and loss of existing wells in mined areas; (2) local drainage of clinker beds adjacent to the mined areas; (3) drainage of the coal and overlying sandstone aquifers along strike in the immediate vicinity of a mine; (4) partial drainage of the coal and overlying sandstone aquifers downdip immediately west of a mine, but primarily a lowering of water levels in wells tapping these aquifers; and (5) little, if any, significant effect on aquifers that underly the coal and crop out east of the mined area.

The areal extent and amount of steady-state drawdown in existing wells that might result from pumping during mining operations depends largely on the permeability and boundary conditions of interrupted aquifers. Although data are not available from which to determine these effects for specific areas, it can be stated as a first approximation that steady-state

drawdown in existing wells will decrease logarithmically with increasing distance from a mine. Drawdown should be most pronounced in wells tapping the thick, areally extensive coal aquifer, which is moderately permeable, and should be relatively minor in those comparatively thin, discontinuous sandstone aquifers interbedded with shale in the overlying Wasatch Formation that are not actually truncated by a mine. It should be stressed again that a sandstone aquifer underlain by shale will tend to drain to the lowest level where it is exposed in a mine wall. This level, and not the bottom of the mine, will be the discharge point to which the new water-level gradient in the sandstone will adjust. Discontinuous aquifers interbedded with shale and not truncated by a mine should be little affected.

An example of the effect of pumping in the Gillette area is shown in figure 12 (in pocket). Water-level observations in a well 320 feet (97.5 m) deep within a mile of the well field that supplies water for Gillette showed no decline that could be attributed to pumping during the period 1950 to 1965. Since 1965, however, the water level has declined steadily in response to significantly increased pumping from the well field. Total decline of the water level over a period of about 8 years has been about 5 feet (1.5 m).

Another example of minimal drawdown exists in the vicinity of the Wyodak mine. Records indicate that mining began at Wyodak in the 1920's and that mining activities during recent years have been restricted to the south pit, which is about 100 feet (30.5 m) deep, remains open, but is not actively mined. Ground-water discharges above a shale parting near the middle of the coal bed where it is exposed on the west side of the north pit. A water well about 1,700 feet (520 m) west of the north pit is 102 feet (31.1 m) deep. The static water level in this well in 1973 was 34 feet (10.4 m) below the surface, which corresponds closely to the level of the old land surface at the north pit. Similarly, a well about 1,500 feet (455 m) south of the south pit is 112 feet (34.1 m) deep. The static water level in this well in 1973 was 28 feet (8.5 m) below the surface, which is about 10 feet higher than the old land surface at the south pit.

Available data, therefore, indicate generally that wells more than a mile from the mined areas probably will be little affected by mining operations. When mining is terminated and water is no longer pumped from the excavated area, ground-water discharge augmented by surface runoff and infiltration from precipitation will tend to saturate the backfill. Eventually, water in the backfill will rise to a level where equilibrium is established between recharge and discharge. If no depressions below the level of saturation are left in the mined area and the basal rubble is moderately permeable, the level of saturation in the mined area should closely approximate pre-mining

levels. Water levels in nearby shallow wells eventually should return to essentially the original levels. If, under similar conditions, the rubble at the base of the backfill is relatively impermeable, water levels in wells that tap the coal bed or overlying aquifers probably would be slightly higher than original levels.

Changes in the quality of water from mining in the Gillette area should not be serious, despite the fact that the mined areas are in a recharge area. As previously stated, downward movement of water is occurring in the proposed mine areas but at a very slow rate because relatively impervious shales lie beneath the coal. The coal and overlying sandstone aquifers discharge water in the bottoms of the stream valleys at the lowest points of outcrop and are a primary source of underflow in these valleys. Therefore, pumping from mined areas should not greatly alter the chemical character of the underflow downstream from a mine. Moreover, available data indicate that water from the coal generally contains less dissolved solids than underflow in the stream valleys. Two wells tapping the coal aquifer near the Wyodak mine yield water containing about 1,500 mg/l dissolved solids. Water from a shallow well in the alluvium adjacent to Donkey Creek about a mile upstream from the mine contains about 1,750 mg/l dissolved solids. Wells tapping the coal near the Amax mine yield water containing about 1,750 mg/l dissolved solids. A well in the alluvium adjacent to Caballo Creek about 5 miles

upstream from the mine yields water containing about 3,500 mg/l dissolved solids.

Water moving downward in the mined area probably would be discharged eventually at the surface a short distance downstream from the mine. It is highly unlikely, therefore, that deeper aquifers in the area would be adversely affected.

Considerable uncertainty exists as to the effects of mining on water quality after the area is rehabilitated. Much depends on the chemical character of the backfill and on the surface configuration of the mined area. Unfortunately, no data are available as to the chemical constituents that might be obtained from rocks in the lower part of the Wasatch Formation, which will be used as backfill in the Gillette area. However, studies by Norman Denson (oral commun., 1974) show that sandstones in the Wasatch Formation in the Powder River Basin contain abundant heavy minerals. Presumably, the shales also have similar characteristics. It is possible therefore, that leachates in the Gillette area may contain high concentrations of objectionable trace elements and/or metals.

If no depressions are left in the mined areas, leach waters will eventually contribute to underflow in streams that drain the area, with consequent contamination of water supplies downstream. If, however, an elongate trench is left along the excavated mine face, a lake could be formed. Because of the westward dip of the beds, and thus a westward-sloping mine floor, leach water from the backfill area should move downslope through the coarse rubble at the base of the backfill toward this lake-filled depression. Depending on its surface area, evaporation from this lake may be sufficient to dissipate all groundwater discharge from the truncated aquifers exposed in the mine face and all leach water from the backfill area. If evaporation offsets inflow, no serious contamination should occur downstream.

Birney-Decker area

Hydrogeologic setting

The Birney-Decker area, as described in this report, has a total area of about 1,400 square miles (3,630 km^2) and includes seven subareas within the larger area (fig. 13, in pocket) that together cover about 150 square miles (390 km^2).

The Birney-Decker area is part of an extensive dissected plateau underlain by essentially flat-lying strata that have been differentially eroded to form a series of great benches or steps that rise toward the high interstream divides (Bass, 1932, p. 27-31). The margins of these benches have been dissected into a myriad of irregular narrow spurs and isolated buttes. Resistant clinker beds commonly mantle the steep barren slopes and cap the flat-topped buttes and ridges that are a characteristic topographic feature in those areas underlain by the Tongue River Member of the Fort Union Formation. Erosion of massive sandstone beds, at places more than 100 feet (30 m) thick, results in prominent sandstone knobs and pinnacles that stand above the rolling surface of the surrounding area. Such landforms are characteristic of several horizons in the Tongue River Member.

The incised Tongue River and its larger tributaries flow in comparatively flat-floored valleys bordered by steep slopes that rise upward to clinker-capped ledges. The Tongue River Valley is 1 to 2 miles (1.6 to 3.2 km) wide and, throughout most of its course within the study area, is bordered by

bluffs that rise as much as 150 feet (46 m) above the valley floor. The flood plain of the river is 0.5 to 1 mile (0.8 to 1.6 km) wide. Flood-plain deposits, as much as half a mile wide, border the larger tributary streams.

The Birney-Decker area is in the northwestern part of the Powder River structural basin. Superposed on the major structural features of the basin are minor folds that generally trend northeastward and roughly parallel the Tongue River Valley, although a few trend northwestward. These minor folds have been mapped in the area west of Hanging Woman Creek by Baker (1929, p. 30-31). The structure contour map of the top of the Pierre Shale (fig. 13) is based on data from oil test holes and on stratigraphic relationships.

Most faults in the Birney-Decker area trend northeastward and have a vertical displacement of less than 50 feet (15 m). Some of these faults probably were produced by differential compaction of sediments in the Fort Union Formation; others may reflect readjustment of surficial materials after the natural burning of underlying coal beds. Some faults are traceable for several miles and many have sufficient displacement to fully offset coal and sandstone aquifers. Van Voast (1974) reports that some faults in the Decker area apparently are effective barriers to ground-water movement in the coal aquifers. As such, they may limit the areal extent of water-level changes caused by mining.

Ground water is the primary source of water for domestic supplies throughout the Birney-Decker area and is an important source of water for livestock. An estimated 1,000 wells and 200 to 300 springs have been developed for stock-water supplies in the area. Where available, surface water is also used for watering livestock and for irrigation. Domestic supplies are generally obtained from developed springs or pumped from wells. Very few wells flow at the surface. The local availability of ground water was a primary consideration in selecting homesteads in the Birney-Decker area. Without water from wells or springs, much of the upland range could not be utilized by domestic animals.

The water-bearing characteristics of formations overlying the Pierre Shale in the Birney-Decker area are summarized in table 3. Rock units yielding water to wells or springs that could be affected by mining include alluvium and aquifers in the Wasatch Formation and in the Tongue River Member of the Fort Union Formation. Wells tapping rock units underlying the Fort Union Formation should not be directly affected by mining.

Aquifers in the Wasatch Formation and in the Tongue River Member include clinker, coal, and sandstone. The clinker is a baked or fused sandstone or shale that characteristically has high secondary porosity and extreme fracture permeability. The clinker aquifer in the Birney-Decker area generally is recharged directly by precipitation and by infiltration from upland ephemeral streams. Where clinker underlies extensive areas, it may yield up to 0.1 ft^3/s (2.8 l/s) of water to

wells and springs; where the clinker caps narrow ridges, it is generally drained. Of all aquifers in the Birney-Decker area, the clinker is the most permeable and yields water having the least amount of dissolved solids. Dissolved solids range from 270 to about 1,300 mg/l.

Coal beds in the Birney-Decker area are sufficiently fractured to be reliable aquifers for domestic and stock-water supplies. This secondary permeability and porosity caused by fracturing occurs throughout the area, but is best developed in those localities where structural deformation is greatest. The fractures probably are related to major structural deformation of the basin as well as to local folding and faulting. The coal beds generally are less permeable than the clinker, but somewhat more permeable than sandstone beds. According to Van Voast (1974), the average hydraulic conductivity of the coal is about 2 feet per day (0.6 m/d). Dissolved solids in water from coal aquifers range from about 1,000 to 2,500 mg/l. Principal constituents are calcium, magnesium, and sulfate.

Most sandstone beds in the Birney-Decker area are lenticular and of relatively small areal extent. Although the hydraulic characteristics of the sandstone beds have not been determined, the lithology indicates that the average hydraulic conductivity is probably 1 to 2 feet per day (0.3 to 0.6 m/d). The hydraulic conductivity of individual beds in the Tongue River Member, however, probably changes greatly over comparatively short distances because of variations in lithology.

Dissolved solids in water from sandstone aquifers range from about 1,500 to about 5,000 mg/l. Principal constituents generally are calcium, magnesium, and sulfate.

The geologic and hydrologic setting of the selected subareas within the Birney-Decker area is summarized in table 4 and figures 14-18 (in pocket). Statements in the table are based on previous studies in the Birney-Decker area, on fieldwork completed specifically for this study, and on an understanding of basic principles of ground-water occurrence. Substantiating field observations and quantitative data must be acquired from additional fieldwork.

Effects of surface mining

Although leachates from spoil materials used for backfill may have a significant local effect on the ground-water system, little is known about the chemical composition of leachates or factors that affect the concentration and movement of leachates. The following discussion summarizes the current knowledge about mine spoils and the subsequent leaching of these materials.

Mine spoils are overburden materials removed in order to expose a coal bed by surface-mining methods. Overburden is used for backfill in those areas after the coal has been excavated. The backfill replaces the pre-existing aquifers and other materials disturbed by mining and introduces new physical and chemical factors into the hydrologic system. Average permeability of the spoils is different in direction and magnitude than the stratified overburden before mining. Chemical constituents not readily available for dissolution before mining become available when the overburden is stripped, aerated, and replaced in a heterogeneous unstratified condition.

Little is known about the hydrologic characteristics of mine spoils in the Fort Union coal region. Current research efforts on the hydrology of spoils are centered near Colstrip, Montana at the Rosebud and Big Sky mines. Although these efforts have not yet produced definitive results, several observations are warranted.

Spoil materials from a mine presumably will be leached by water moving through the broken materials, either laterally or vertically, or both. Concentrations of dissolved solids should increase in the direction of movement through the spoil deposits and should depend in large part on the composition, rate of chemical weathering, and permeability of the spoils and on the rate of ground-water movement through these materials. The excavated overburden has a volume about one-fifth greater than that of the undisturbed rock (V. W. Carmichael, North American Coal Corp., oral commun., 1974). This increase in volume probably results in an increase in both porosity and permeability (at least vertical permeability). Furthermore, during mining operations, the mine floor generally is covered by a thin stratum of coarse rubble composed of wasted coal and of boulders that have rolled down from nearby spoil piles. These strata probably have significantly greater permeability in the horizontal direction than the overlying comparatively fine-grained backfill materials. Quantitative data for the hydraulic conductivity of spoil materials are provided by Van Voast (1973) for the Rosebud mine near Colstrip. Although these data are inconclusive, they indicate that the average hydraulic conductivity ranges from 0.07 to 7 ft/day (0.002 to 2.3 m/d). This range is too broad for dependable calculations of ground-water flow.

Chemical analyses of simulated spoils have been published for the Colstrip area (Hodder and others, 1970) and for the Decker area (Hodder and Sindelar, 1972). Principal cations in materials from the Colstrip area are calcium and magnesium; sodium concentrations are relatively low. Excavated materials near Decker contain substantially higher concentrations of sodium, calcium, and magnesium; sodium concentrations are about ten times those of samples collected near Colstrip.

Leachates from spoil deposits near Colstrip (Van Voast, 1973, and Montana Bureau of Mines and Geology, unpublished data) contained much higher dissolved-solids concentrations than waters sampled from nearby wells tapping shallow aquifers. Calcium and magnesium concentrations were much higher than sodium. Also, water samples from spoil materials contained small concentrations of trace metals (copper, lead, zinc, and nickel) not found in other waters in the area. Leachate from spoil materials near Decker is not yet available for analysis. However, the relatively high concentrations of sodium in water from aquifers in that area correspond to the high sodium concentrations found by Hodder and Sindelar (1972) in leachate from simulated spoils. If simple projections are valid, spoil leachates in the Decker area should be more highly mineralized than those in the Colstrip area, and the principal cations should be sodium, calcium, and magnesium.

Still unpredictable, however, are the probable dissolved-solids concentrations and volumes of spoil leachates that will be generated within specific mine areas. Although paths of

travel and probable destinies of these waters can be approximated for most proposed mine areas in the Birney-Decker area, the chemical constituents, concentration, and volume of the leachates must be known to predict their effect on the environment.

Following are comparisons from Van Voast (1973) of water samples from two wells in the Colstrip area, Montana. One well taps old spoil materials and the underlying Rosebud coal bed; the other taps an unmined coal bed. Parameters are in mg/l.

	Water from old spoils and the Rosebud coal bed	Water from the unmined coal bed
Date of collection	9-25-73	9-25-73
Calcium (Ca)	467	53
Magnesium (Mg)	351	51
Sodium (Na)	114	190
Potassium (K)	9.0	8.1
Iron (Fe)	1.82	.26
Manganese (Mn)	1.25	.07
Silica (SiO_2)	16.0	14.3
Bicarbonate (HCO_3)	483	553
Carbonate (CO_3)	0	0
Hydroxide (OH)	0	0
Chloride (Cl)	15.9	4.1
Sulfate (SO_4)	2418	284
Nitrate (NO_3)	15.5	1.1
Fluoride (F)	.1	.1
Calculated dissolved solids	3892	1159

Strip mining in the Birney-Decker area will involve removal of several aquifers. Selection of sites for mining will determine which aquifers will be affected and how far the effects will extend. For example, a mine that penetrates the full thickness of alluvium in a stream valley to reach the underlying bedrock and coal probably will affect not only nearby wells in the bedrock, but will decrease the amount of water in

the alluvium and possibly degrade the quantity and quality of streamflow for a considerable distance downstream. Conversely, a mine that penetrates only bedrock and is located in a ground-water discharge area may lower water levels in nearby wells and decrease the yield of nearby springs, but the effect on water quality probably can be contained within the developed area. Mines that penetrate bedrock in ground-water recharge areas can also be expected to adversely affect nearby wells and springs. Special precautions, however, may be needed to prevent leakage of poor quality water into underlying aquifers. In other respects the effects of mining in the Birney-Decker area should be similar in principle to those in the Gillette area, and the discussion is not repeated here.

PRELIMINARY ANSWERS TO QUESTIONS POSED BY WATER WORK GROUP

To facilitate use and summarization by the Water Work Group of material presented in this report, answers to specific questions posed by the Water Work Group are given in table 5.

FUTURE OUTLOOK

In addition to the questions posed in the Introduction to this report, new questions have been raised that generate more uncertainty and require more effort to answer than did the original questions. The most important new questions are as follows: How will the regional ground-water system in the Powder River and Williston Basins be affected by full-scale mining and consequent development of water supplies for power generation and gasification plants? What are the rock-water chemical reactions that occur in spoil deposits, and how can predictions be made of the general quality and ion concentration of spoil leachates? What are the values for the parameters that control movement of water through the coal, and what effect does the coal have on the quality of water in these aquifers? In the selection of sites and development of mining plans, how can knowledge of the regional flow system be used to minimize ground-water depletion and contamination? Answers to these questions will do much to prevent needless damage to the ground-water resource as coal production increases.

Concepts presented in this report need to be confirmed and improved if the impacts of current and future mining on the regional ground-water system are to be fully understood. Baseline data, including a thorough inventory of wells and springs, aquifer testing, test drilling, and analyses of water samples, need to be collected throughout the northern Great Plains coal area. Data describing the occurrence of trace substances, including radioactive elements, are needed and are almost entirely lacking.

Regional geologic and geophysical studies of the shallow aquifers are needed to determine variations in geology that affect the flow system. Guidelines need to be established for management of existing ground-water supplies and for orderly development of this resource in the future.

Because spoil leachates probably will be highly mineralized and may contain objectionable concentrations of trace elements, research is needed to define the chemical reactions that occur with time in spoil deposits. An understanding of the chemistry and the direction and rate of flow of leachates is needed in planning for prevention of serious contamination in mine areas.

Movement of water through beds of coal is controlled largely by fractures, but fracture systems in coal are poorly understood. Barriers to and avenues for ground-water flow in coal aquifers need to be defined generally and located specifically in mine areas, if the local effects of mining are to be predicted and unnecessary deleterious effects minimized. The effects of coal on the quality of water are almost completely unknown, but may be critical in some problem areas. For example, it may be possible to use unmined comparatively thin, noncommercial coal beds to filter out and retain objectionable trace elements from spoil leachates.

Each mining development probably will present unique ground-water problems. To properly cope with these problems, predevelopment studies are needed to define the local ground-water flow system and to develop a monitoring network. These

studies of relatively small areas need to be related to the regional flow system to properly appraise the feasibility of alternate plans for developing and protecting the ground-water resource.

Evaporation ponds and solid-waste disposal sites can be located properly to prevent needless local contamination of the ground-water resource only if hydrologic data from pre-development studies are used in mine planning. To minimize contamination from evaporation ponds in recharge areas, research is needed to develop economical techniques for preventing leakage from these ponds.

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ILLUSTRATIONS

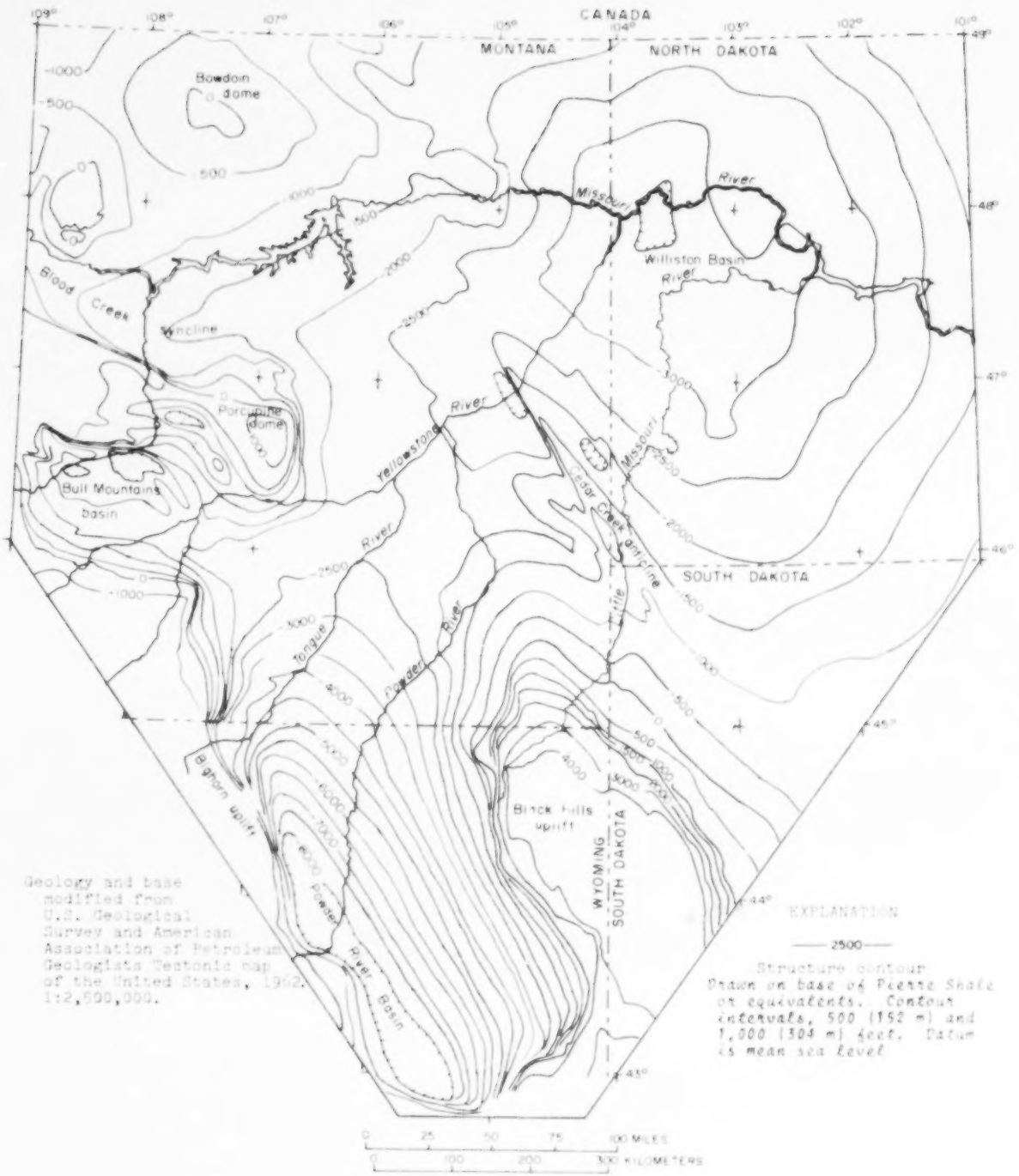
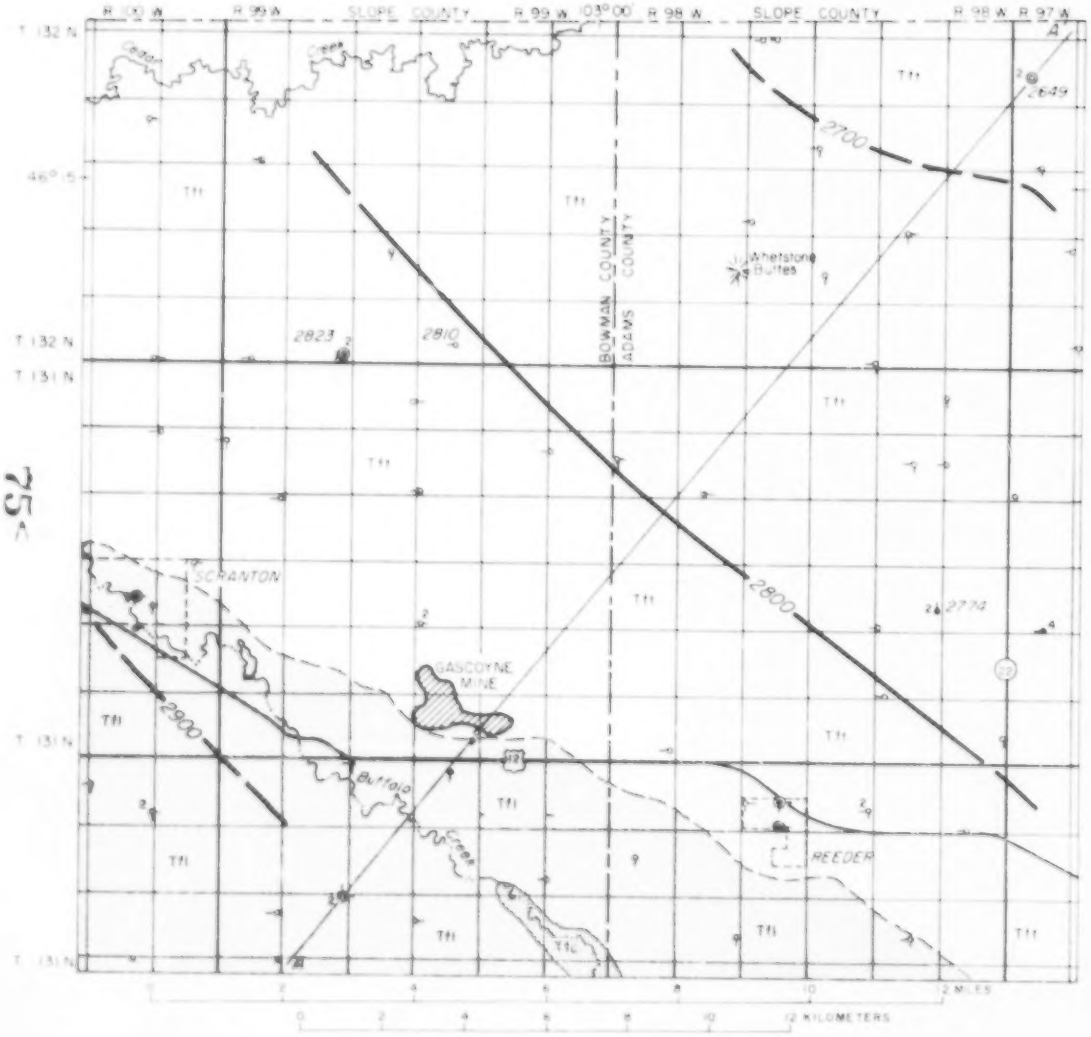


Figure 3.--Tectonic map of the northern Great Plains coal region.



EXPLANATION

Paleocene — TERTIARY

Tft
Tfl
Tfc

FORT UNION FORMATION
Tft Tongue River Member
Tfc Cannonball Member
Tfl Ludlow Member

Contact--Dashed where approximate

Strip-mine area

A——A' Line of section (fig. 7)

2800 Potentiometric contour--Shows altitude of potentiometric surface of water in the Tongue River-upper Ludlow aquifer. Dashed where inferred. Contour interval 100 feet (30.5 m). Datum is mean sea level

2774 Test hole--Number is altitude of water level, in feet above mean sea level. 1 foot = 0.3048 meter

2810 Domestic or stock well--Number is altitude of water level, in feet above mean sea level. 1 foot = 0.3048 meter

Public supply or industrial well

Commercial test hole

MODIFICATIONS USED WITH ABOVE SYMBOLS

Specific conductance in tables

Water-level measurements in table

Chemical analysis in table

2 Number of wells at location

Figure 6.--Geologic map showing locations of wells and test holes in Gascoyne area, North Dakota.

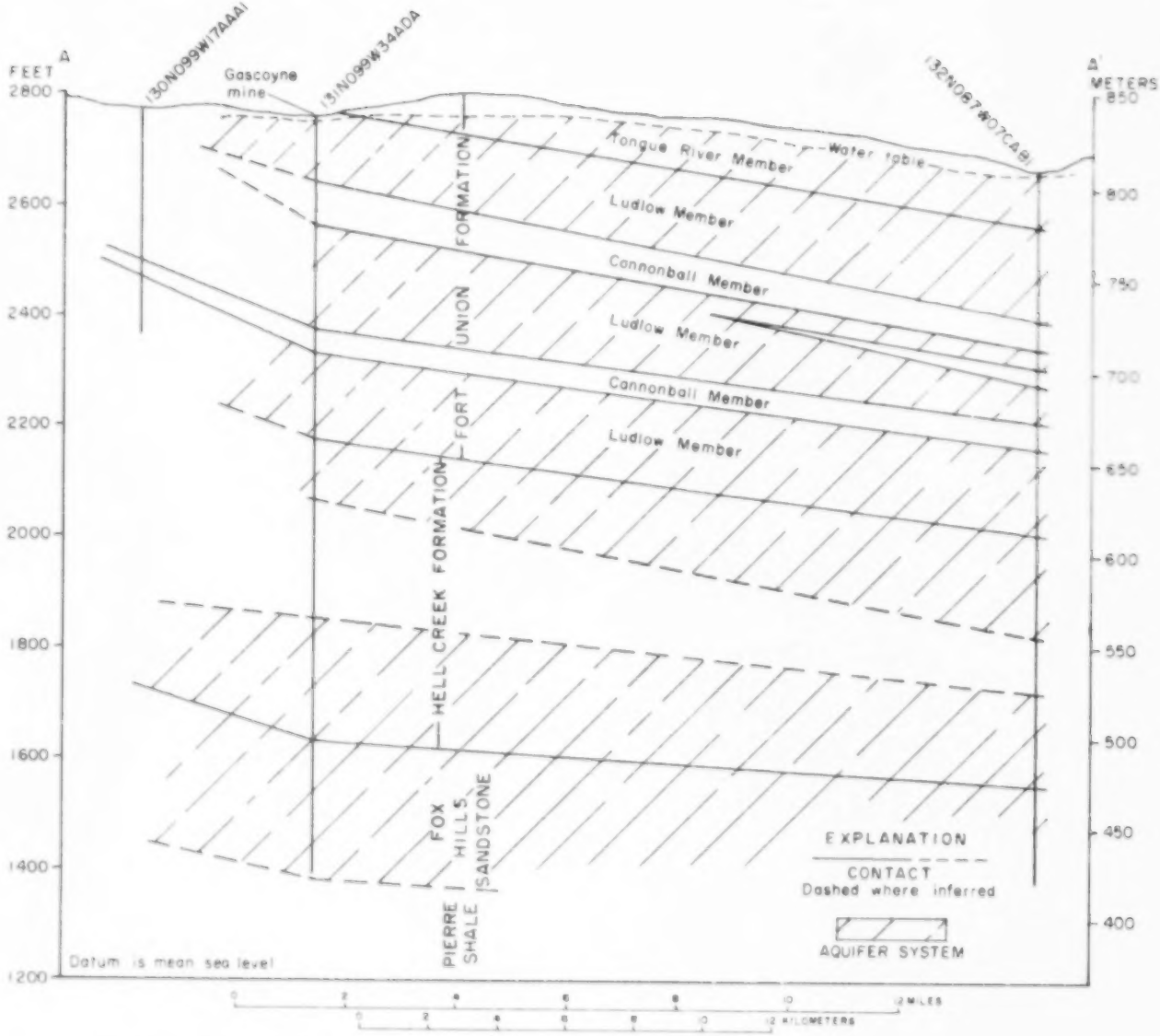


Figure 7.—Hydrologic section A-A', Gascoyne area, North Dakota, (see figure 6 for line of section).

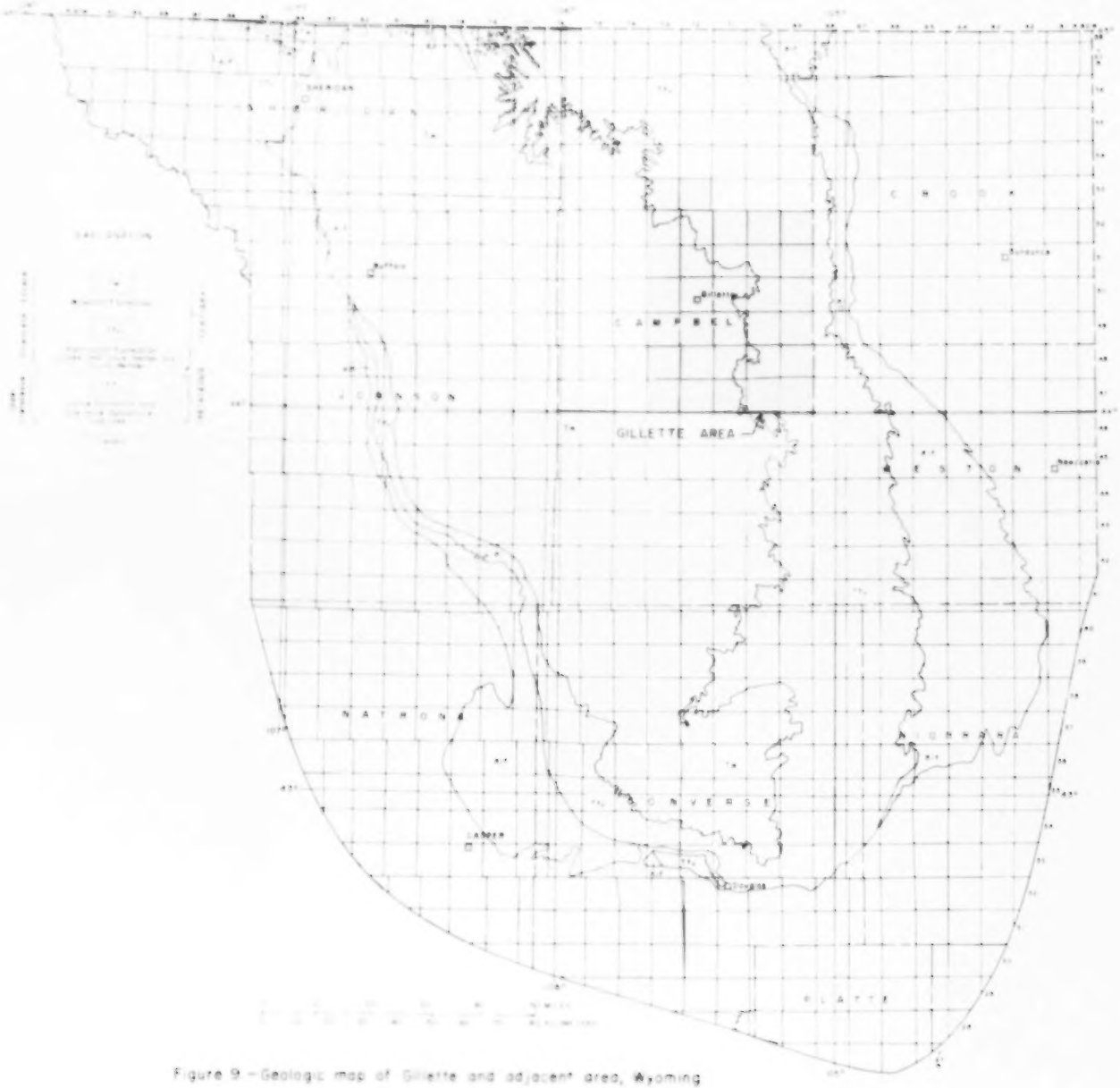


Figure 9.—Geologic map of Gillette and adjacent area, Wyoming

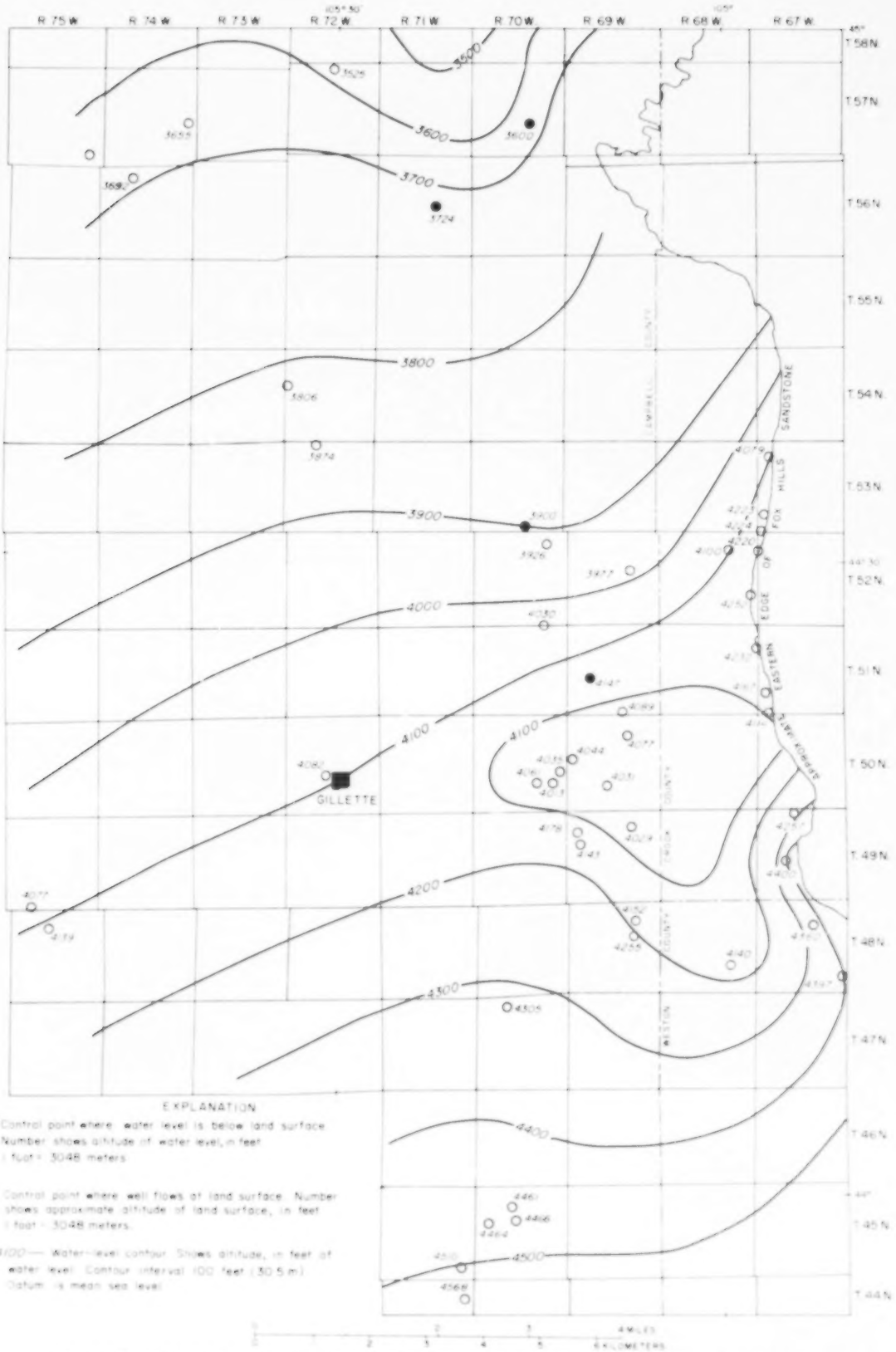


Figure 10.—Contours on water levels in wells finished in the Fox Hills Sandstone, Lance Formation, and lower part of Fort Union Formation in the Gillette area, Wyoming.

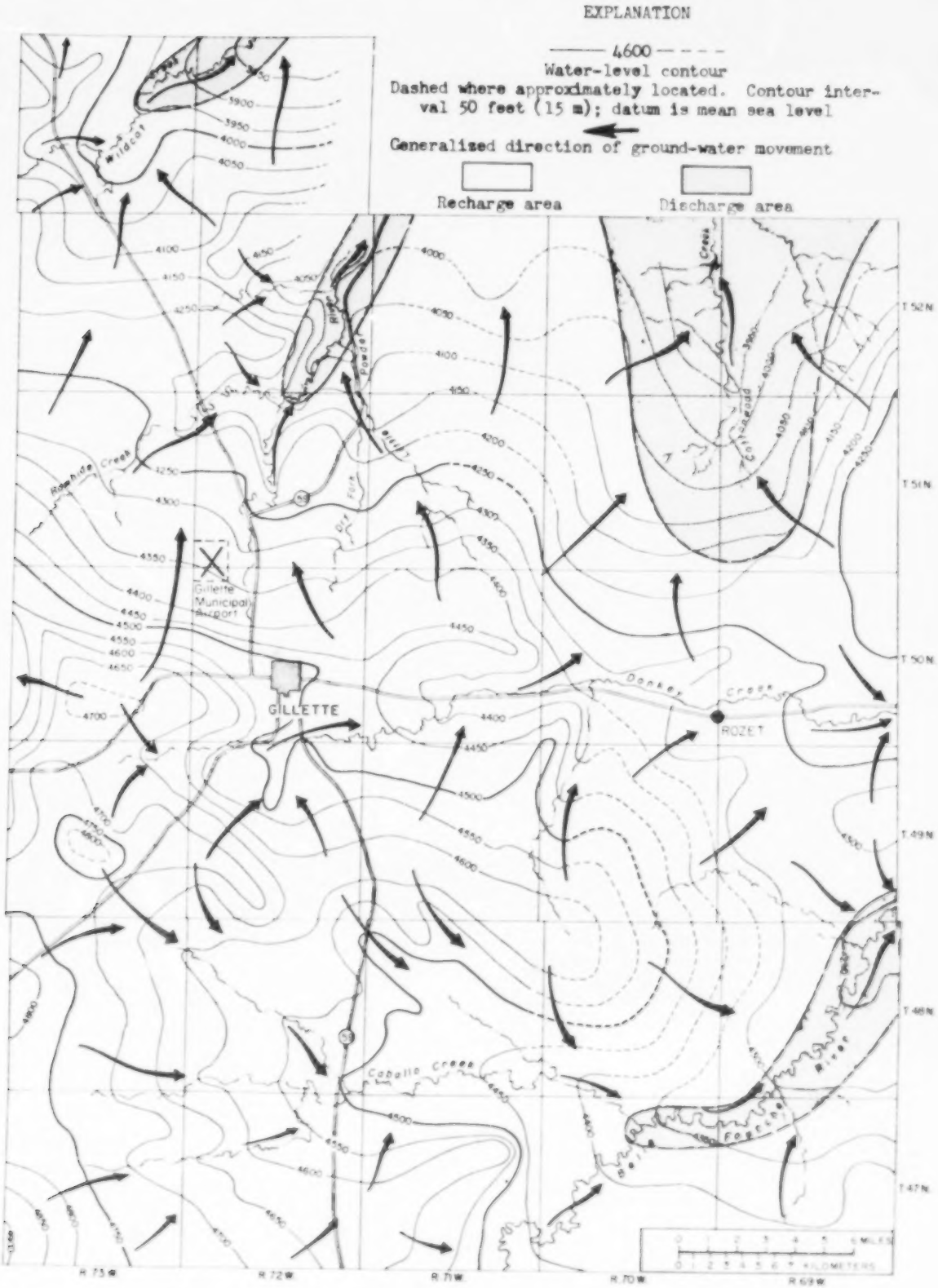


Figure 11.—Water levels and direction of horizontal movement of ground water in the Fort Union and Wasatch Formations in the Gillette area, Wyoming. (Modified after King, 1974)

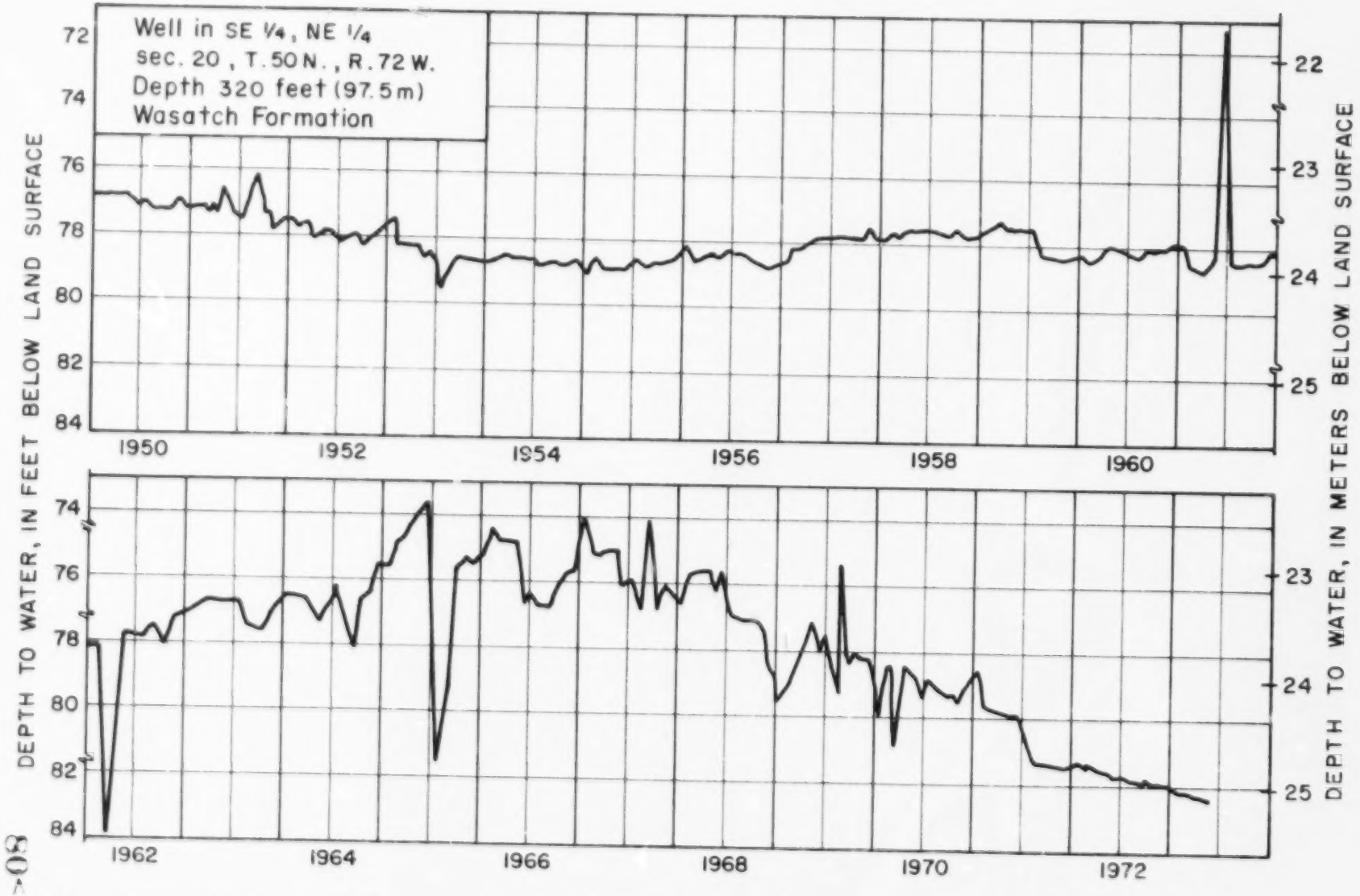
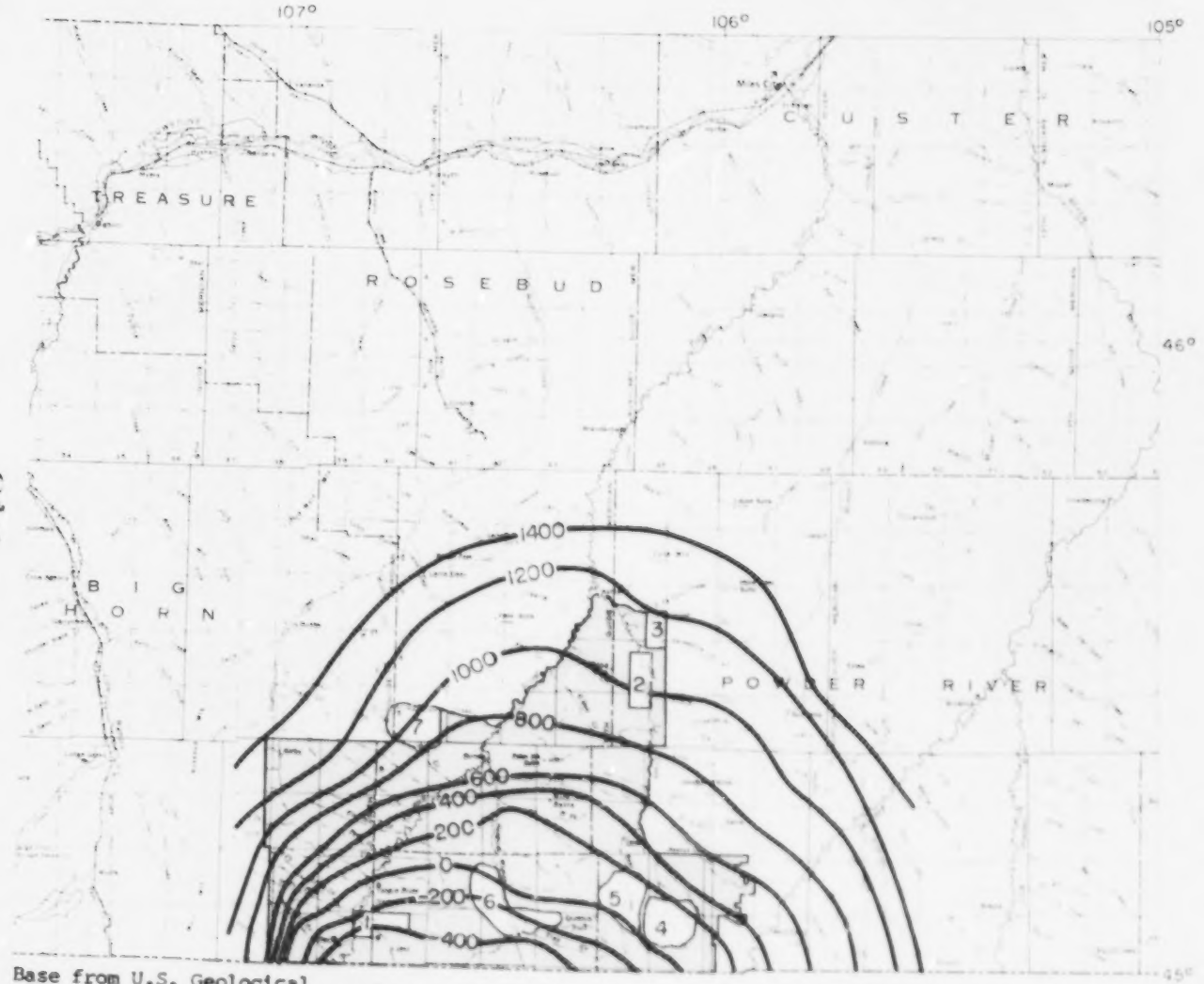


Figure 12.- Water-level changes in the Wasatch Formation near Gillette, Wyoming.



Base from U.S. Geological Survey State base map, 1:1,000,000

EXPLANATION

Birney-Decker area

600

Structure contour
Shows altitude of top of the Pierre Shale. Contour interval 200 feet (61 m); datum is mean sea level

PRIORITY SUBAREAS

1 -- Decker East
2 and 3 -- Lower Otter Creek
4 and 5 -- Upper Otter Creek
6 -- Hanging Woman Creek
7 -- Cook Creek

Figure 13.--Location of subareas in Birney-Decker area, and structure contours on top of the Pierre Shale.

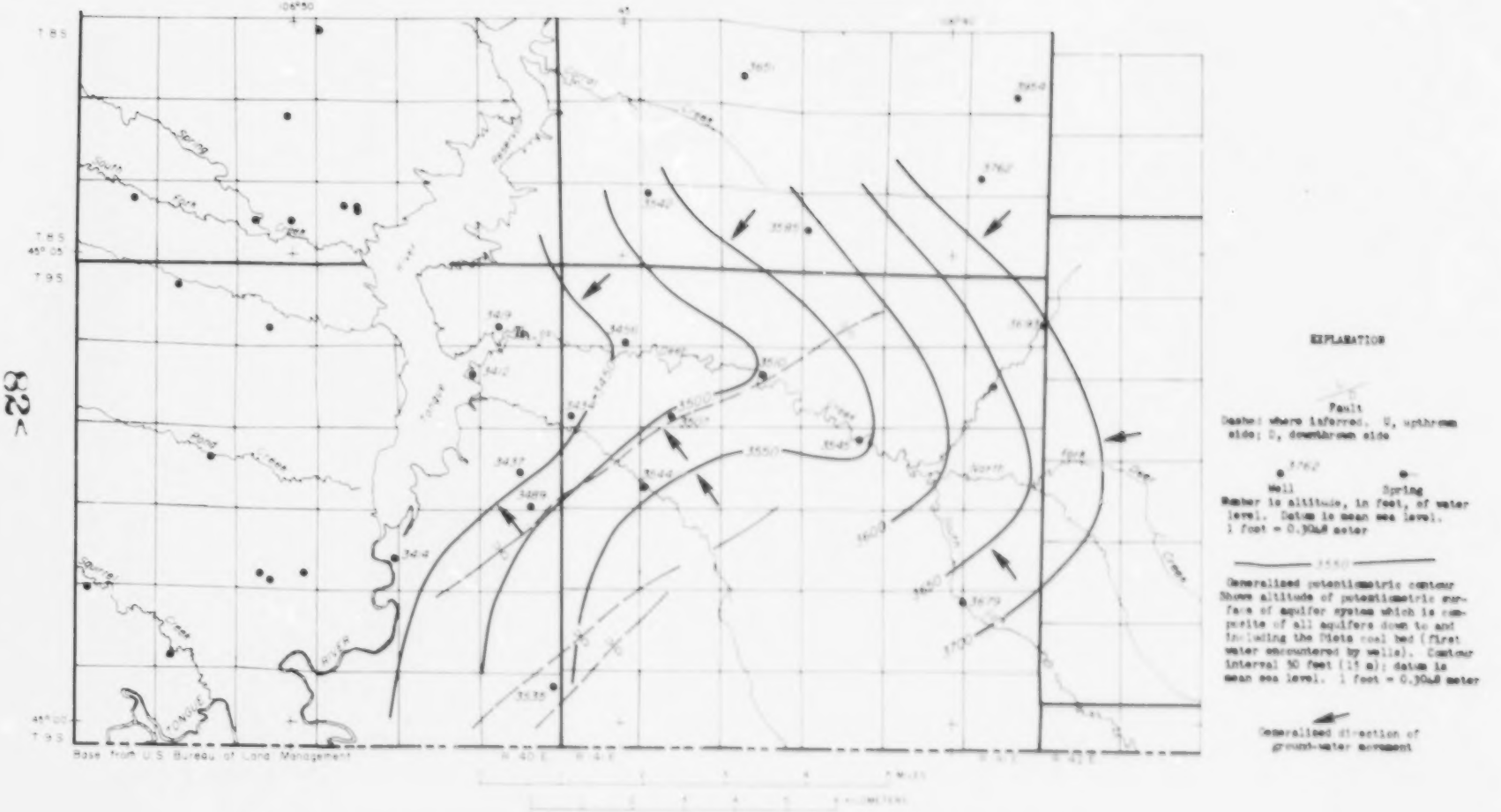

EXPLANATION
Fault
Dashed where inferred. U, upthrown side; D, downthrown side
Well
Spring
Number is altitude, in feet, of water level. Datum is mean sea level. 1 foot = 0.3048 meter
Generalized potentiometric contour Shows altitude of potentiometric surface of aquifer system which is composite of all aquifers down to and including the Dietz coal bed (first water encountered by wells). Contour interval 50 feet (15 m); datum is mean sea level. 1 foot = 0.3048 meter
Generalized direction of ground-water movement
Base from U.S. Bureau of Land Management

FIGURE 14-HYDROGEOLOGIC MAP OF DECKER EAST AREA, SOUTHEASTERN MONTANA

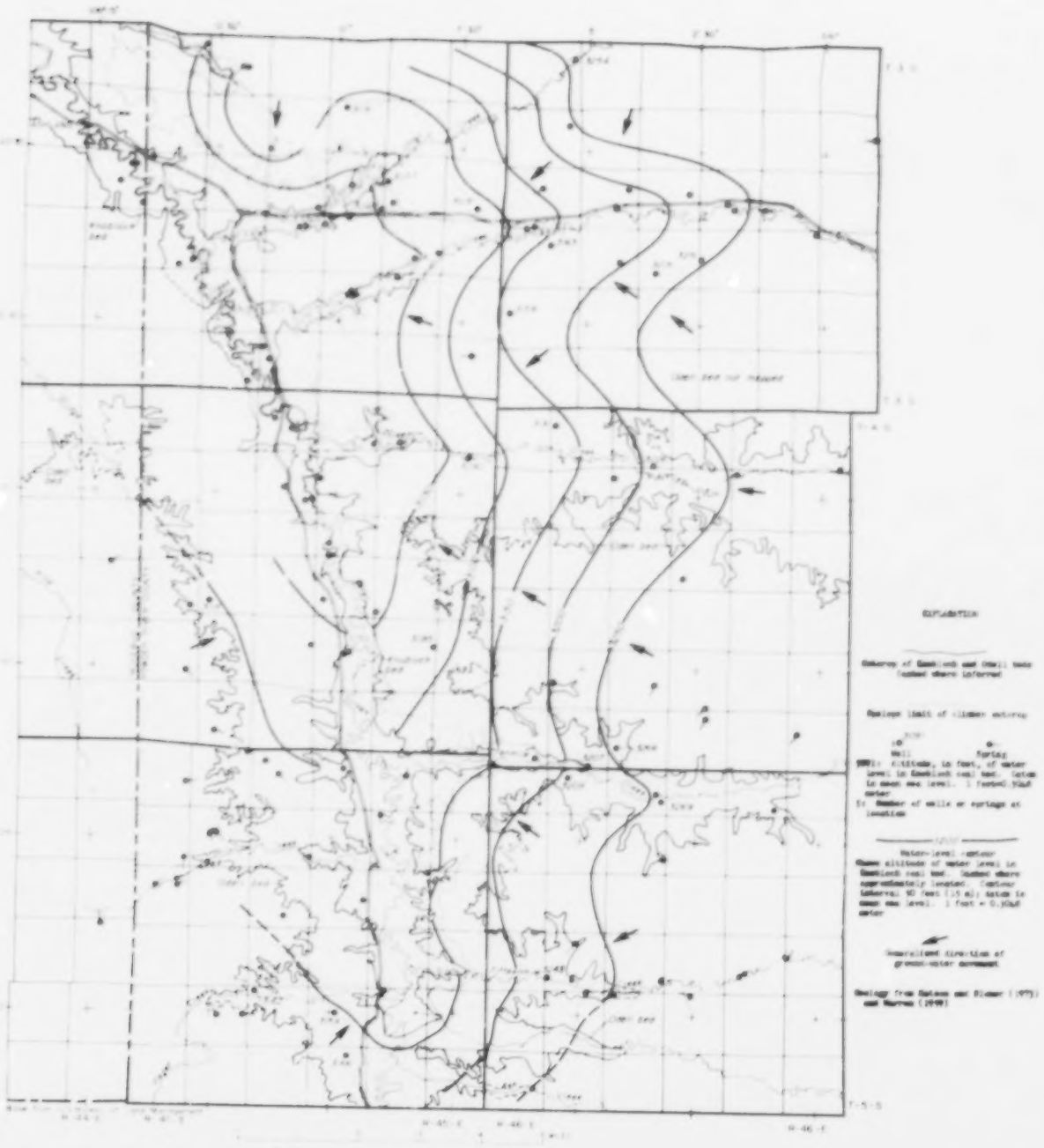


FIGURE 15.--HYDROGEOLOGIC MAP OF LOWER OTTER CREEK AREA, SOUTHEASTERN MONTANA

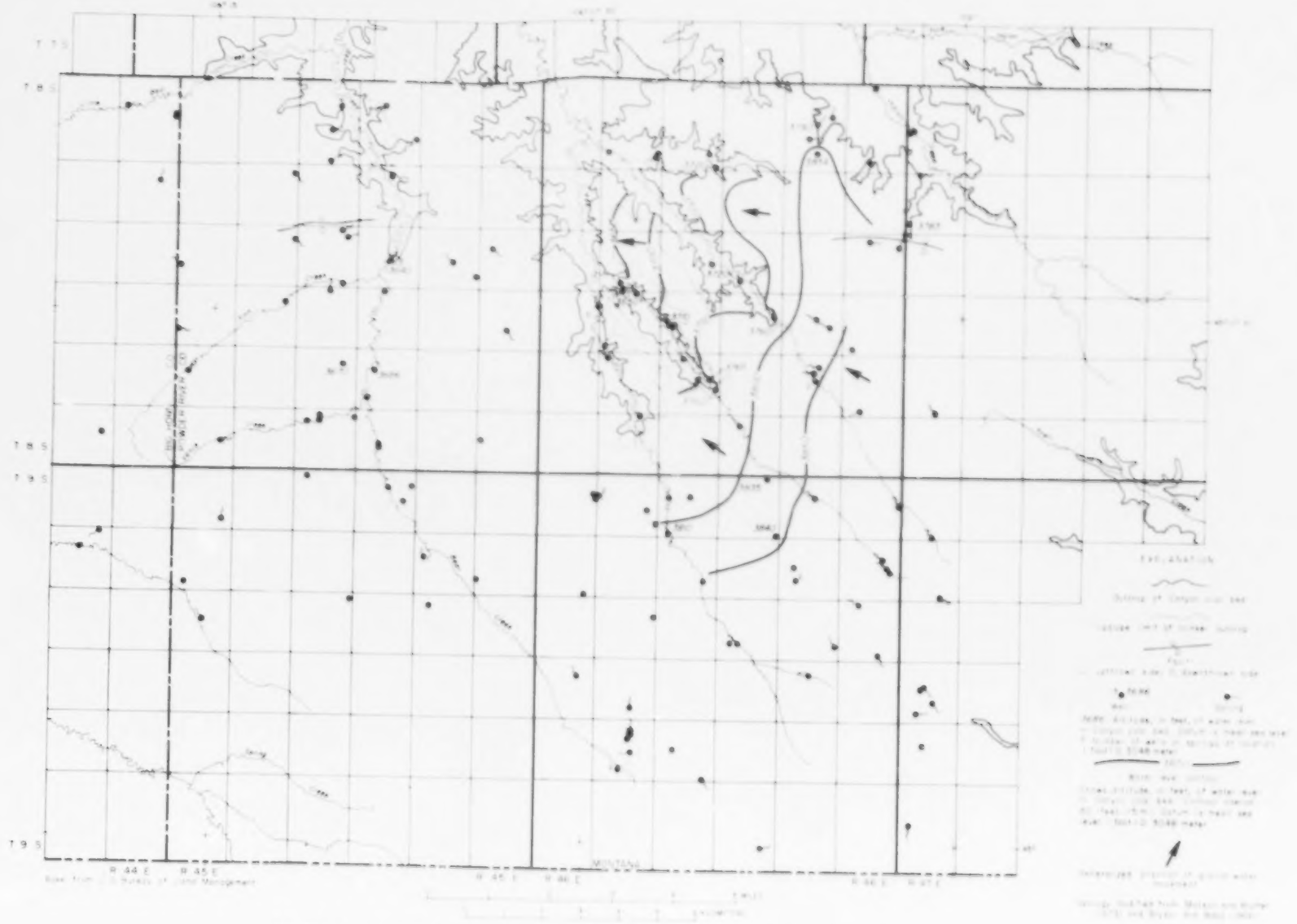


FIGURE 16.--HYDROGEOLOGIC MAP OF UPPER OTTER CREEK AREA, SOUTHEASTERN MONTANA

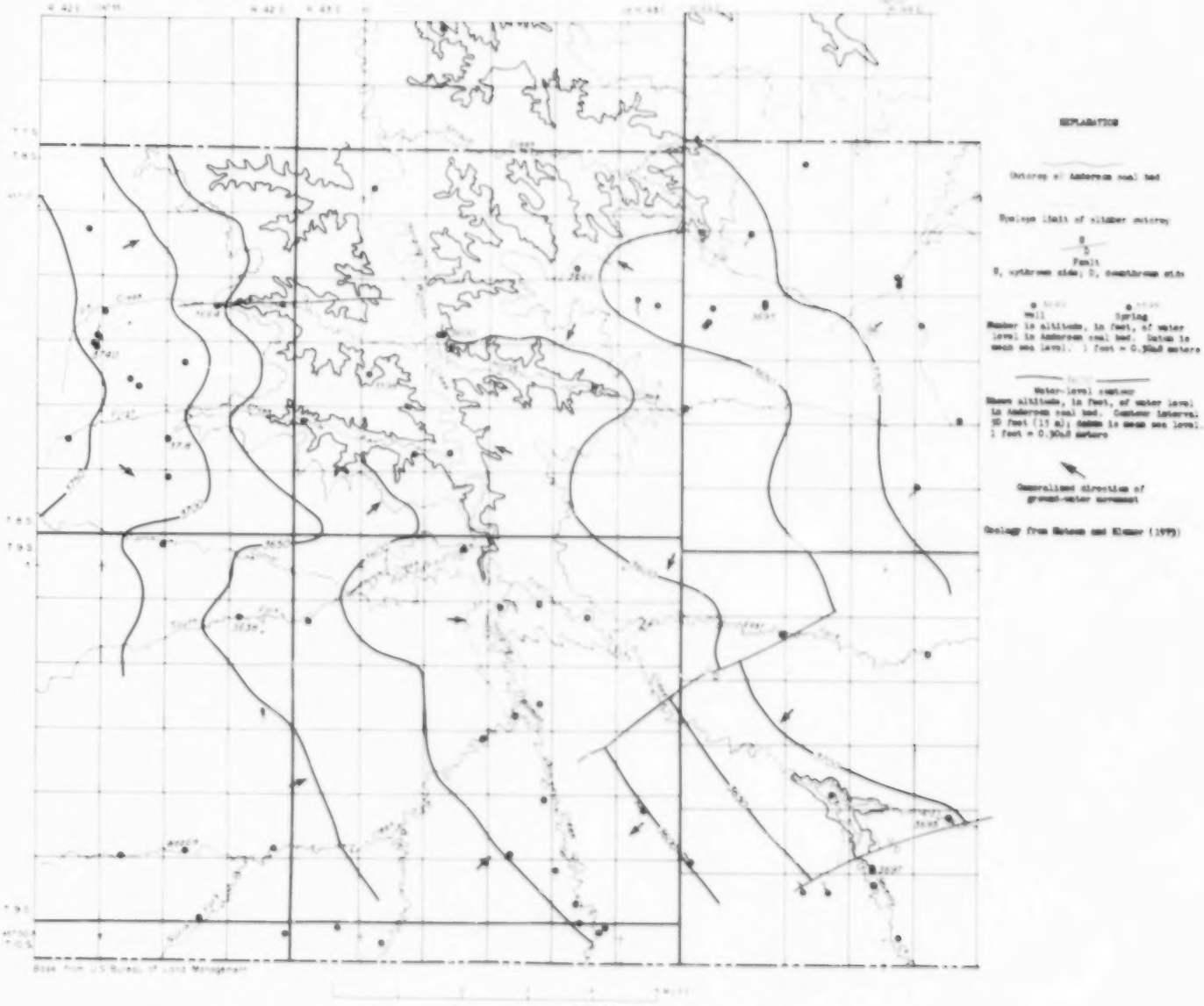


FIGURE 17.–HYDROGEOLOGIC MAP OF HANGING WOMAN CREEK AREA, SOUTHEASTERN MONTANA

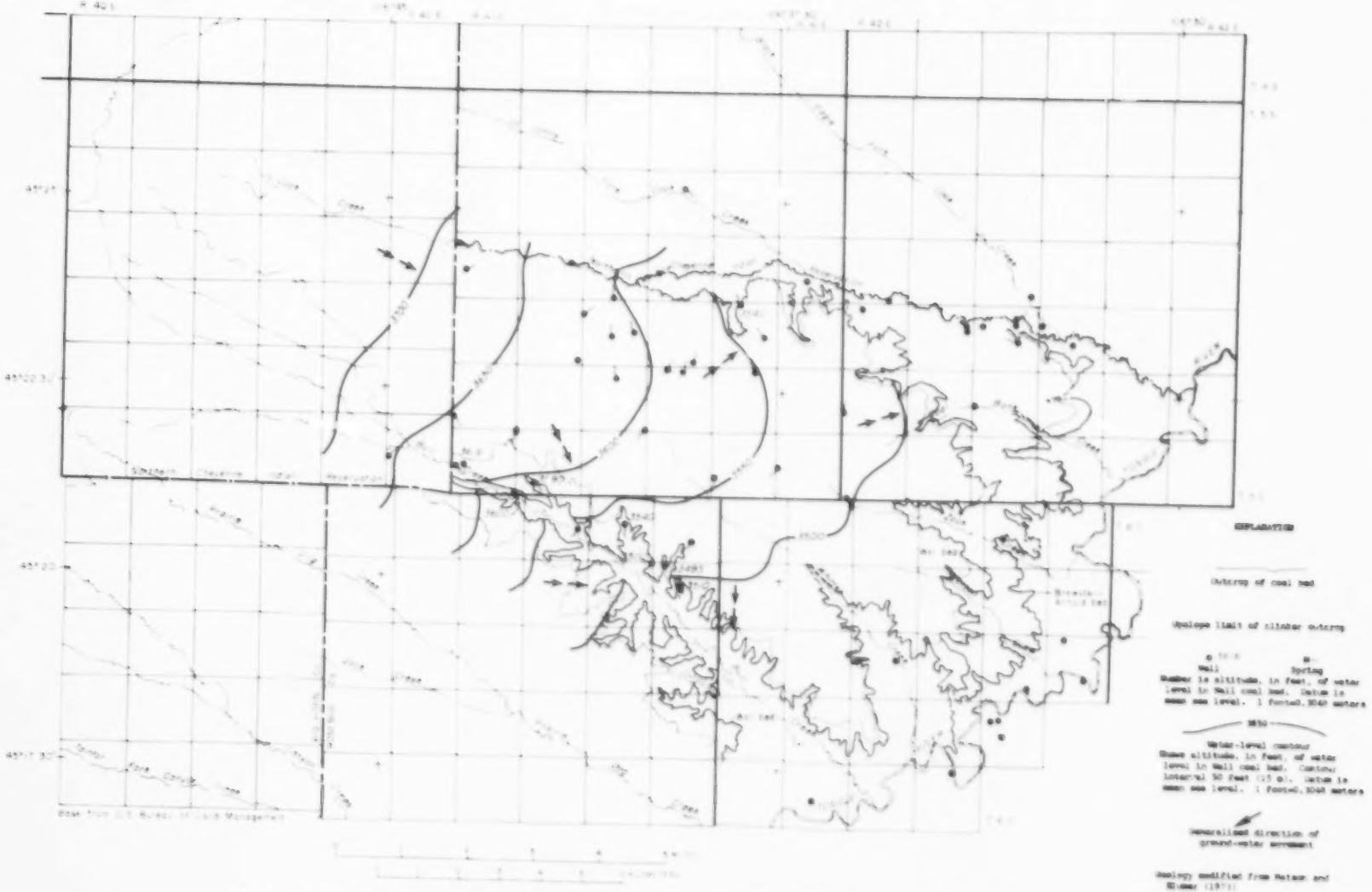

EXPLANATION
Outcrop of coal bed
Apalogo limit of clinker outcrop
Well
Spring
Number is altitude, in feet, of water level in Wall coal bed. Datum is mean sea level. 1 foot=0.3048 meters
Water-level contour
Shows altitude, in feet, of water level in Wall coal bed. Contour interval 50 feet (15 m). Datum is mean sea level. 1 foot=0.3048 meters
Generalized direction of ground-water movement
Geology modified from Matson and Blumer (1973)

FIGURE 18.—HYDROGEOLOGIC MAP OF COOK CREEK AREA, SOUTHEASTERN MONTANA

TABLES

Table 1.--Generalized stratigraphic section for southwestern North Dakota (modified from Benson and Hill, 1965)

System	Series	Group, formation, member	Thickness (feet)	Lithologic characteristics
Quaternary	Holocene and Pleistocene		0-250	Silt, sand, and gravel in dunes, terraces, and alluvial fans along main stream channels south of the Missouri River. Pleistocene deposits, glacial and glaciofluviatile in origin, cover a large part of the region north of the Missouri River; deposits include alluvium, eskers, kames, and glacial outwash sand and gravel.
Tertiary	Pliocene or upper Miocene	Flaxville Formation and probable correlatives	0-180	Sandstone and conglomerate, poorly cemented, overlain at some places by beds of volcanic ash and white marlstone. Basal unit is widespread pediment deposit that caps even-topped plateaus ranging in altitude from 3,600 ft on Sheep Mountain in northeastern Montana to about 2,500 ft along the Montana-North Dakota State line. Not recognized in southeastern Montana and northwestern South Dakota, but may be a partial correlative in these areas to local pediment deposits along the flanks of the major buttes. These deposits are composed of clayey siltstone, fine-grained sandstone, and gravel derived and reworked from the Arikaree and older formations. Vertebrate fossils in the Ekalaka Hills indicate a Pliocene(?) age.
		Unconformity		
	Miocene	Arikaree Formation	260+	Massive greenish-white to light-gray tuffaceous sandstone and siltstone and a few thin beds of quartzite, dolomite, and volcanic ash.
		Unconformity		
	Oligocene	White River Group: Brule Formation	0-250+	Massive buff to pinkish-tan tuffaceous siltstone, nodular claystone, and channel sandstone. Contains abundant vertebrate remains. Well exposed in Chalky Buttes and Little Badlands of North Dakota. Preserved in pre-Arikaree landslide blocks in the Slim Buttes and Short Pine Hills of South Dakota. Absent or poorly represented in southeastern Montana.
		White River Group: Chadron Formation	0-190	Dark-gray bentonite and light-gray tuffaceous claystone, siltstone, sandstone, and arkose at many places interbedded with thin beds of lenticular limestone. Lower part at many places weathers golden yellow.
		Unconformity		
	Eocene and Paleocene	Golden Valley Formation	0-175	Gray to yellow sandstone, siltstone, and purplish-gray to white kaolinitic clay. Contains a few thin lenticular beds of lignite and carbonaceous shale.
	Paleocene	Fort Union Formation: Sentinel Butte Member	600-950	Dark-gray bentonitic claystone and shale, and buff to brown sandstone.
		Fort Union Formation: Tongue River Member	650	Massive gray to tan sandstone, siltstone, and shale. Contains many lenticular beds of quartzite and thick persistent beds of lignite.
		Fort Union Formation: Cannonball Member	0-300	Cannonball Member: marine dark-gray and brown sandstone and shale. Contains large limy concretions. Extends from the east into northern Perkins and northeastern Harding Counties, S. Dak., and southern Adams and southeastern Bowman Counties, N. Dak. Thins to the west and intertongues with the Ludlow Member. Not recognized west of R. 8 E., northeastern Harding County, S. Dak.
		Fort Union Formation: Ludlow Member	0-400	Ludlow Member: gray to light yellow-tan sandstone, gray shale, and thick lenticular beds of lignite.
Cretaceous	Upper Cretaceous	Hell Creek Formation	400-575	Dark-gray bentonitic claystone and gray-brown lenticular sandstone. Many concretions and thin lenses of iron carbonate. Contains thin lenses of lignite in upper part.
		Fox Hills Sandstone	75-300	Marine grayish-white to brown and ochreous-yellow glauconitic sandstone and interbedded greenish-gray marine shale.
		Pierre Shale	1,700-2,500	Marine dark-gray to brownish-black bentonitic claystone and shale containing large limestone concretions and thin beds of bentonite.

Table 2.--Water-bearing characteristics of geologic units in the Gascoyne area, North Dakota

Formation or Member		Aquifer				
Name	Lithology	Name	Thickness (feet)	Depth (feet)	Transmissivity (ft^2/d)	General water type
Fort Union Formation Tongue River Member	Sandstone and siltstone, fine- to medium-grained, massive, quartzitic; interbedded with claystone and persistent beds of lignite.	Tongue River-upper Ludlow	60-270	10-40	0-300	Sodium sulfate to sodium bicarbonate; many water samples colored various shades of brown; dissolved solids range from 643 to 1,950 mg/l.
Ludlow Member	Sandstone and siltstone, fine- to medium-grained; interbedded with claystone and lignite.					
Cannonball Member	Claystone and siltstone.	Mainly confining beds	0-50	70-280		
Ludlow Member	Sandstone and siltstone; interbedded with claystone and lignite.	Middle Ludlow	100-200		20-200	Sodium bicarbonate; may be colored; dissolved solids range from 1,010 to 1,610 mg/l.
Cannonball Member	Claystone and siltstone.	Confining beds	30-50	250-460		
Ludlow Member	Sandstone and siltstone, fine- to medium-grained; interbedded with claystone and lignite.	Lower Ludlow-upper Hell Creek	260-340	430-510	250-350	Sodium bicarbonate; some samples high in sulfate and may be colored; dissolved solids range from 997 to 1,430 mg/l.
Hell Creek Formation	Sandstone and siltstone, fine- to medium-grained; interbedded with carbonaceous claystone.					
	Claystone and siltstone.	Confining beds				
	Sandstone and siltstone, fine- to medium-grained; interbedded with carbonaceous claystone.	Basal Hell Creek-Fox Hills	470	910-950	150-270	Sodium bicarbonate; most water samples are clear; dissolved solids range from 1,040 to 1,130 mg/l.
Fox Hills Formation	Sandstone and siltstone, fine- to medium-grained, clayey, greenish-gray.					

Table 1.—Principal rock units and their general hydrologic properties in the Pecos River basin

System	Series	Rock unit, formation, member, or equifer	Thickness (feet)	Lithologic character and distribution	General water-bearing characteristics
Quaternary	Holocene and Pleistocene	Alluvium and valley-fill	0–80	Unconsolidated deposits of interbedded clay, silt, sand, and gravel; most gravel is siliceous fragments. Thickest deposits occur along Tongue and Pecador Rivers, and principal tributaries; thinner deposits occur along smaller tributaries. Alluvium is as much as 80 feet thick in Tongue River Valley near Ashland and as much as 50 feet thick along smaller streams.	Wells yield as much as 500 gpm to irrigation wells in the Tongue and Powder River Valleys; probably small yields up to 100 gpm along Otter and Hanging Woman Creeks and Bella Fourche River. Yields less than 10 gpm to stock and domestic wells in rest of basin. Water normally contains about 1,000 mg/l dissolved solids. Calcium, magnesium, and sulfate are the major constituents.
	Holocene and Pleistocene(?)	Flaxville, Flaxville(?), or upper Arikaree(?)	Terrace deposits	0–50+	Sand, gravel, silt, and clay. Terrace deposits confined mainly to valley sides and uplands along Tongue and Powder Rivers and principal tributaries; deposits are scattered in other parts of basin.	Most terraces are small in extent, topographically high, and drained of water. Locally, wells yield as much as 10 gpm to domestic supplies.
Tertiary	Upper Eocene	Wasatch Formation	0–1,500	Clay, in varied-grained lenticular beds of sandstone and siltstone; shale and coal. Coarse-grained deposits are generally most abundant in the southwestern part of the basin. Beds of clinker ring out along the coal outcrops, caused from the southern edge of the basin as burning northward to about the Montana-Wyoming line.	Most wells are shallow and yield less than 25 gpm; however, wells reaching coarse-grained deposits in large alluvial thicknesses yield more than 100 gpm. Dissolved solids range from less than 500 to more than 5,000 mg/l and hardness range between 10 and 1,000 mg/l. Sodium bicarbonate and sodium sulfate are the dominant types of water.
		Tongue River Member of Fort Union Formation	1,400–1,600	Mixed part of formation (Tongue River Member) consists of light-yellow to light-gray, fine- to medium-grained, thick-bedded to massive, locally crossbedded, calcareous sandstone and siltstone, moderate buff, to dark olive-colored light-buff to light-gray shale siltstone and shale, brown to black carbonaceous shale, and moderate coal beds as much as 100 feet thick. Many coal beds have burned along their outcrops forming thick clinker and baked shale beds. The Tongue River Member ranges from 1,400 to 1,600 feet in thickness, but is not mapped locally as a separate unit in drawing.	Sandstone beds are the principal source of water to wells in the Tongue River Member. Yields of wells are as much as 100 gpm in the Powder River Basin, but generally are less than 10 gpm in the Tongue River Basin. Water is generally soft to moderately hard, but is very saline in some parts of the basin. Dissolved solids range from 500 to 5,000 mg/l. Sodium bicarbonate and sodium sulfate are the dominant types of water.
		Lebo Member of Fort Union Formation	1,000–1,200	Dark-gray to dark-brown carbonaceous shale, gray to brown siltstone, and fine- to medium-grained, light-gray sandstone. Sandstone beds are lenticular and generally thin. Coal beds are as much as 100 feet thick in the Powder River Basin, but generally are less than 10 feet thick in the Tongue River Valley. The Lebo Member ranges from 1,000 to 1,200 feet in thickness, but is not mapped locally as a separate unit in drawing.	Yields as much as 10 gpm to domestic wells in the Tongue River Valley; stock wells are as much as 1,000 feet deep. Water is soft to moderately hard, but is very saline in some parts of the basin. Dissolved solids range from 500 to 5,000 mg/l. Sodium bicarbonate and sodium sulfate are the dominant types of water.
		Tullock Member of Fort Union Formation	1,000–1,200	Lower part of formation (Tullock Member) is interbedded sandstone, light-gray shale, light-gray mudstone and thin coal beds; grades to light-gray to light-brown sandstone, gray shale, and grades to black carbonaceous shale. The Tullock Member ranges from 100 to 500 feet thick in the Powder River Basin. The member is not mapped locally as a separate unit in drawing, but a lithologic boundary about 1,000 feet thick is present in the northern part of the basin.	Yields as much as 10 gpm to domestic wells in the Powder River Basin where wells are as much as 1,000 feet deep. Water is soft to moderately hard, but is very saline in some parts of the basin. Dissolved solids range from 500 to 5,000 mg/l. Sodium bicarbonate and sodium sulfate are the dominant types of water.
		Hell Creek Formation, Lance Formation, and Fort Union Formation	500–1,200	Gray to yellowish-gray, clayey, silty, sandy, carbonaceous and fossiliferous shale and siltstone; locally in Montana and throughout most of the Powder River Basin is drawing yellowish-gray to tan, fine- to medium-grained, silty sandstone predominates.	Not tapped by wells in the Powder River Basin but in other areas is reported to yield as much as 10 gpm to domestic wells and to springs. Yields of as much as 100 gpm are believed possible in the unconsolidated part of the basin in drawing. Depth to the top of the formation is as much as 1,000 feet in the Powder River Basin and about 2,000 feet near Billings. Water is probably similar in type and total dissolved solids to that in Tullock Member of Fort Union Formation.
Cretaceous	Cretaceous	Upper Cretaceous	Fox Hills sandstone	Bear Butte Creek Member Fox Hills equivalent	0–500	Gray to yellowish-gray to light-brown, fine- to medium-grained sandstone, containing gray shale claystone and siltstone that locally constitutes a large part of the lower part of the aquifer, locally. Grading to crossbedded sandstone near the top containing thin beds of bentonitic shale.	Yields as much as 10 gpm to domestic-stock livestock wells and as much as 20 gpm to municipal-industrial wells. Yields as much as 500 gpm to industrial wells. In Powder River area, water is under artesian pressure. Depths to top of the aquifer range from 1,500 to 4,000 feet in the Powder River area. In the central part of the Powder River Basin is drawing locally to the top are about 4,000 feet. Water is likely to be a sodium bicarbonate type, and contains as much as 1,000 mg/l dissolved solids. Fluoride concentrations exceeding 1 mg/l commonly occur in water from deep wells in drawing.
			Pierre Shale	2,000+	Gray and black shale claystone and shale; some rock-bedded siltstone and silty sandstone, locally calcareous shallow bentonite.	Not known to yield water to wells area, in a confining and

Table 4.--Hydrogeologic setting of subareas, Sheep-Decker area, Montana

Subarea	Physiography of subarea--drainage, surficial features	Local structure--attitude of beds in relation to regional structure, presence of identified folds or faults	Lithology--stratigraphy of units likely to be affected by mining, important aquifers	Description of aquifers--includes water-bearing beds that may not be affected by mining as well as those that will be	Description of aquifer[illegible] ...ruining patterns of exp... of beds beneath valleys
Deer Creek Priority area number 1	Upland dissected by Deer Creek and its tributaries; valley drains to Tongue River. Valley incised 250 to 300 feet below upland. Flood plain of Deer Creek about 0.25 to 1.25 miles wide.	Small structural depression plunges southeast; small dome in center of T. 9 S., R. 41 E. Several northeast-trending anticlines, synclines, and faults occur in the southeast part of area.	Bedrock is sandstone, coal, and shale in the upper part of Tongue River Member of the Fort Union Formation; includes Anderson, Dietz No. 1, and Dietz No. 2 coal beds. Ulkner beds cover most of the area. Alluvium in valley of Deer Creek is less than 40 feet thick; alluvium along Tongue River is less than 40 feet thick.	Bedrock aquifers crop out near Tongue River Reservoir and extend eastward in the subsurface. Sandstone and coal beds below level of Tongue River are continuous throughout area.	Anderson and Dietz coal reliable aquifers, may a few places. Sandstone below the level of Tong reliable aquifers. Coal beds above the Anderson to be drained. Alluvia Deer Creek is principal Ulkner fragments to e clay. Saturated thickn extent, water-table cond probable, average perme larger than for coal a variable. Ulkner beds the Anderson and Dietz facilitate recharge; th higher than for coal a Ulkner is drained in
Lower Otter Creek Priority areas number 2 and number 3	Area is drained by Otter Creek. Flood plain as much as 1 mile wide; flood plains on tributaries as much as 0.25 mile wide. Topography is rugged along east-flowing tributaries and moderate in rest of area. Total relief is about 1,200 feet, local relief is as much as 600 feet. The area is highly dissected, mainly by east-flowing streams.	Regional dip of the Knobloch coal is southeastward at about 10 feet per mile; small anticline is center of area. No faulting has been identified.	Bedrock is sandstone, coal, and shale in the lower part of the Tongue River Member. Alluvium is gravel, sand, and silt and is probably less than 50 feet thick. Major coal beds are the Knobloch, Anderson, Dietz, and Ulkner beds. Most coal beds are directly overlain or underlain by water-bearing sandstones. Outcrop areas of the Knobloch coal have burned to form extensive clinkered areas.	The main aquifer is the Knobloch coal bed, which crops out along Otter Creek (fig. 15). Other aquifers, in order of importance, are the sandstones of the Tullock Member of the Fort Union Formation (which yields water to flowing wells as much as 1,200 feet deep), sandstone and coal beds and associated clinker overlying the Knobloch coal bed, and the alluvium. Clinkered areas of the Knobloch and overlying coal beds are important both as recharge areas to underlying rocks and as aquifers.	The Knobloch coal bed c Otter Creek and some of The other coal be a sig valley slope. The Tull the Fort Union Formati subsurface. The alluvi the streams.
Upper Otter Creek Priority areas number 4 and number 5	Located on interstream divide between Otter Creek and Powder River. Topography moderate to steep, total relief in area about 500 feet, as much as 700 feet locally. Moderately dissected by Otter Creek and its tributaries. Stream valleys usually less than 0.5 mile wide, stream gradients about 30 ft/mile.	Beds dip gently southeastward. A small northwest-plunging anticline is T. 8 S., R. 41 E., has been mapped. Two east-trending faults have been identified.	Bedrock is sandstone, coal, and shale in the upper part of Tongue River Member. The unconformable alluvium overlies Fort Union Formation from the ridge tops in T. 9 S. R. 41 E. The alluvium is gravel, sand, and silt; is less than 50 feet thick, and is less than 0.5 mile wide. The major coal beds are the Canyon, Dietz, Anderson, Smith, and Dietz coals. Extensive clinker deposits occur in the valley sides where the Anderson coal beds have burned.	Main aquifers are Roland, Anderson, and Canyon coal beds and the sandstone adjacent to the coal. Ulkner and the alluvium are aquifers in places. The Anderson and Canyon coal beds are probably saturated, except in outcrop areas where they have been partially drained to springs and seeps.	The [illegible] of the [illegible] shown on Figure 15, t northeast, west, and ...tance of [illegible] Powder River drainage ...ributaries of Hanging Woman
Hanging Woman Creek Priority area number 6	Upland dissected by Hanging Woman Creek and its tributaries. Valley walls are steep, up to 400 feet of relief. Valley bottom of creek is nearly 0.5 mile wide, stream meanders across alluvium, which is probably less than 40 feet thick.	Beds dip gradually southward (maximum 2 degrees, S.E. which flexures mostly into creek. A southplunging anticline is intersected by faults in T. 8 S. Hanging Woman Creek approximately follows the anticline axis. East-trending fault cited across T. 8 S. (map), displacement less than 40 feet.	Bedrock in the upper part of the Tongue River Member and includes the Roland, Smith, Anderson, and Dietz No. 1 coal beds. Intervening beds are sandstone and shale. Ulkner underlies most of the upland areas and is as much as 50 feet thick. The alluvium is as much as a mile wide and 40 feet thick.	Bedrock aquifers include Smith, Anderson, and Dietz No. 1 coal beds. Alluvium along Hanging Woman Creek supplies several wells. Ulkner appears to be an important aquifer.	[illegible] confined to ...Woman Creek and its t...ent coal bed lutting ...Ulkner from Anderson ...the sides of valleys ...Hanging Woman Creek. ...is from 50 to 70 feet ...Anderson bed.
Pine Creek Priority area number 7	Upland ridges slope toward Tongue River, dissected by Pine, Whitten, and Bull Creeks, all of which are ephemeral. Ridges are steep-sided and capped by clinker. Alluvium not extensive.	Beds dip southeastward as much as 50 feet per mile; no faulting noted along Pine Creek.	Bedrock in the middle part of Tongue River Member, includes Canyon and Wall coal beds. Brewster-Arnold coal bed outcrops area all along Tongue River. Intervening beds are fine-grained sandstone and shale. Ulkner is moderately extensive and in places more than 40 feet thick.	Principal aquifers are the coal beds Canyon, Wall, and Brewster-Arnold--and Ulkner. The Brewster-Arnold bed is a reliable aquifer, upper coal beds are partly dissected and partly drained. Wells completed in sandstone and coal beds below the Brewster-Arnold coal bed flow in areas along Tongue River.	Ulkner underlies th... Pine and Bull Creeks ...coal beds crop out ...along Pine, Whitten ...Brewster-Arnold coal ...along Tongue River.

Table 4.--Hydrogeologic setting of subareas, Birney-Decker area, Montana

...ude of beds in ...al structure, presence ...ds or faults	Lithology--stratigraphy of units likely to be affected by mining, important aquifers.	Description of aquifers--includes water-bearing beds that may not be affected by mining as well as those that will be.	Description of aquifer boundaries--outcrop patterns of exposed beds, extent of beds beneath valleys.	Areas of ground-water discharge--determinations from structure and from potentiometric mapping.	Quality of water in aquifers--report primarily on analytical tables.
...pression plunges ...down in center of ... Basin; northeast-..., synclines, and ...the southeast part of	Bedrock is sandstone, coal, and shale in the upper part of Tongue River Member of the Fort Union Formation; includes Anderson, Dietz No. 1, and Dietz No. 2 coal beds. Clinker beds crop out east of the area. Alluvium in valley of Deer Creek is less than 40 feet thick. Alluvium along Tongue River is less than 10 feet thick.	Bedrock aquifers crop out near Tongue River Reservoir and extend eastward in the subsurface. Sandstone and coal beds below level of Tongue River are continuous throughout area.	Anderson and Dietz coal beds are reliable aquifers, may be drained in a few places. Sandstone and coal beds below the level of Tongue River are reliable aquifers. Sandstone and coal beds above the Anderson coal bed appear to be drained. Alluvium in valley of Deer Creek is principally reworked clinker fragments to sand, silt, and clay. Saturated thickness is not known, water-table conditions are probable, average permeability is larger than for coal or sandstone, but variable. Clinker beds associated with the Anderson and Dietz coal beds facilitate recharge, permeability is higher than for coal or alluvium, but clinker is drained in most of the area.	Alluvium discharges to Tongue River and by evapotranspiration. Anderson coal beds and associated clinker discharge water along north side of Deer Creek and possibly along east side of Tongue River. Deeper aquifers in Tongue River Member of the Fort Union Formation discharge water to alluvium by upward leakage through poorly permeable beds.	Dissolved solids in water from the bedrock aquifers exposed at the surface ranges from 2,900 to 8,100 mg/l, principal ions are sodium, magnesium, and sulfate. Data are not available describing the quality of water in aquifers below the Tongue River. Dissolved solids in water from the clinker deposits is less than 1,000 mg/l.
...Knobloch coal is ...about 20 feet per mile, ...n center of area. No ...identified.	Bedrock is sandstone, coal, and shale in the lower part of the Tongue River Member. Alluvium is gravel, sand, and silt and is probably less than 50 feet thick. Major coal beds are the Knobloch, Flowers, Canner, and Ideal beds. Most coal beds are directly overlain or underlain by water-bearing sandstones. Outcrop areas of the Knobloch bed have caused by fires extensive clinkered areas.	The main aquifer is the Knobloch coal bed, which crops out along Otter Creek (fig. 15). Other aquifers, in order of significance, are the sandstones of the Tullock Member of the Fort Union Formation which yields water to flowing wells as much as 1,000 feet deep), sandstone and coal beds and associated clinker overlying the Knobloch coal bed, and the alluvium. Clinkered areas of the Knobloch and overlying coal beds are important both as recharge areas to underlying rocks and as aquifers.	The Knobloch coal bed crops out along Otter Creek and some of its tributaries. The other coal beds crop out in the valley slope. The Tullock Member of the Fort Union Formation is in the subsurface. The alluvium occurs along the streams.	Potentiometric contours indicate that the Knobloch coal bed discharges water to the alluvium along Otter Creek. Water is moving into the area from the northeast, east, south, and east. Water from underlying aquifers is discharged upward. Discharge from aquifers overlying the Knobloch is mainly from springs and seeps along outcrops and from wells. Discharge from the alluvium is by underflow northward and by evapotranspiration.	Dissolved solids in the water from the Knobloch coal range from about 900 to 1,100 mg/l. The principal ions are magnesium, sodium, sulfate, and bicarbonate. Water from deeper wells that tap the Knobloch contains principally sodium and bicarbonate. Water from wells completed below the Knobloch coal bed, either in the lower Tongue River or Tullock Members of the Fort Union Formation contains sodium and bicarbonate as the principal ions and dissolved solids range from about 1,900 to 2,800 mg/l. Water from wells and springs that discharge from rocks above the Knobloch coal bed contains magnesium, sodium, sulfate, and bicarbonate as principal ions. Dissolved solids range from about 400 to 5,700 mg/l. Water from the alluvium contains mainly magnesium and sulfate. Dissolved solids range from about 1,100 to 1,600 mg/l.
...Otterstreet - A small ...anticline in T. 8 S., ... mapped. Two east-...have been identified.	Bedrock is sandstone, coal, and shale in the upper part of Tongue River Member. The ...ologically similar sequence Formation from the ridge line in T. 8 S., R. 43 E. The ...luvium is gravel, sand, and silt, is less than 10 feet thick, and is less than 0.5 mile wide. The main coal beds are the Knobloch, Canner, Anderson, Dietz, and Ridge coal. Extensive clinker ...deposits on the valley sides where the Knobloch coal bed is burned.	Main aquifers are Roland, Anderson, and Canyon coal beds and the sandstone adjacent to the coal. Clinker and the alluvium are aquifers in places. The Anderson and Canyon coal beds are probably saturated, except in outcrop areas where they have been partially drained by springs and seeps.	The limits of the Canyon coal bed are shown in figure 16, the beds extend northeast, east, and south beyond limits of figure, cropping out in the Powder River drainage and along tributaries of Hanging Woman Creek.	Flow in Canyon bed is generally eastward away from the ground-water divide between Otter Creek and Powder River. Otter Creek intercepts flow of the Pine Flow between aquifers is downward. The Canyon bed is partly drained where it is dissected along Otter Creek.	Water from springs and shallow wells is hard, contains calcium, magnesium, and sulfate as major ions. Dissolved solids range from 470 to 1,700 mg/l. Water from springs issuing from clinker contains lowest concentrations of dissolved solids, principal ions are calcium, magnesium, and bicarbonate. Other springs contain higher concentrations of dissolved solids and sodium and sulfate are major ions. Water from wells more than 100 feet deep is usually soft, contains sodium and bicarbonate as major ions, dissolved solids range from about 2,900 to 3,800 mg/l.
...southeast trend that ...ver flexures mostly ...ault-plunging syncline ...Route 12 T. 9 S., ...an approximate ...dinal axis. Beds ...ped along T.9 S. ...s than 40 feet.	Bedrock in the upper part of the Tongue River Member and includes the Roland, Smith, Anderson, and Dietz No. 1 coal beds. Intervening beds are sandstone and shale. Clinker underlies most of the upland areas and is as much as 50 feet thick. The alluvium is as much as a mile wide and 20 feet thick.	Bedrock aquifers include Smith, Anderson, and Dietz No. 1 coal beds. Alluvium along Hanging Woman Creek supplies several wells. Clinker appears to be an important aquifer.	Alluvium confined to valleys of Hanging Woman Creek and its tributaries. Anderson coal bed outlined shown on figure 17. Clinker from Anderson bed extends along the sides of valleys tributary to Hanging Woman Creek. Dietz coal bed is from 50 to 70 feet below the Anderson bed.	Alluvium discharges water to Hanging Woman Creek and by evapotranspiration. Consolidated beds discharge water to clinker and to alluvium. Potentiometric map shows flow of water in Anderson coal bed and associated clinker is toward Hanging Woman Creek.	Water in consolidated aquifers above the Anderson coal bed contains principally magnesium, sodium, and sulfate, dissolved solids range from about 2,000 to 4,000 mg/l. Water in the Anderson clinker contains principally sodium, sulfate, and bicarbonate, dissolved solids range from about 1,000 to 2,000 mg/l. Water in the Anderson coal bed contains principally sodium and bicarbonate, dissolved solids range from about 1,000 to 1,500 mg/l. Water in the Dietz coal bed contains principally sodium and sulfate, dissolved solids range from about 1,500 to 2,000 mg/l.
...ward as much as 80 ...a faulting noted along	Bedrock in the middle part of Tongue River Member, includes Canyon and Wall coal beds. Brewster-Arnold coal bed underlies area and crops out along Tongue River. Intervening beds are silty-bedded sandstone and shale. Clinker is moderately extensive and in places more than 50 feet thick.	Potential aquifers are the coal beds--Canyon, Wall, and Brewster-Arnold--and clinker. The Brewster-Arnold bed is a reliable aquifer; upper coal beds are partly dissected and partly drained. Wells completed in sandstone and coal beds below the Brewster-Arnold coal bed flow in areas along Tongue River.	Clinker underlies the upland between Otter and Pine Creeks. Canyon and Wall coal beds crop out in valley sides along Otter, Whitten, and Pine Creeks. Brewster-Arnold coal bed crops out along Tongue River Valley.	Ground water discharged from seeps and springs at base of coal and clinker beds. Water from aquifers below Brewster-Arnold coal bed discharges into alluvium along the Tongue River.	Specific conductance of water in clinker generally less than 1,000 micromhos, water in coal beds ranges from about 1,000 to 4,000 micromhos, water in deeper beds ranges from about 1,100 to 2,000 micromhos. Results of analyses of samples not yet available.

Table 5.--Preliminary answers to questions posed by Water Work Group

Question	Answer				
	Beaver Creek Priority area number 1	Lower Otter Creek Priority areas number 2 and number 3	Upper Otter Creek Priority areas number 4 and number 5	Hanging Woman Creek Priority area number 6	Tank Creek Priority area number 7
Will the water supply from aquifers supporting farm-ranch wells be interrupted? Can deeper drilled wells replace the supplies with water of equivalent quality prior to restoration of mined areas?	Water levels in wells tapping the Anderson or Dietz coal beds will be interrupted within and adjacent to mined areas. If a mine intersects the alluvium underlying Deer Creek Valley, the Allen mine will be at least partly affected. Deeper drilled wells to aquifers below the level of the Tongue River should obtain water having about the same or lower concentration of dissolved solids as water from interrupted aquifers. Water from the deeper aquifers probably will be a sodium bicarbonate type and should be suitable for most farm-ranch uses.[1/] Although water from the alluvium characteristically is low in dissolved solids and can be replaced only by water of inferior quality, no wells obtain water from the alluvium, and no springs discharge from coarse rocks in this area.	The water supply from wells tapping the Knowlton coal bed and/or overlying aquifers, including alluvium, will be interrupted within and adjacent to mined areas. Wells tapping deeper aquifers should not be adversely affected. Deeper drilled wells can replace interrupted supplies with comparable yields. Water from aquifers underlying the Knowlton coal bed is generally a sodium bicarbonate type and should contain about the same range of concentration of dissolved solids as the interrupted supplies. The replacement supplies, therefore, should be of approximately equivalent quality for most farm-ranch uses.[1/]	The water supply from wells tapping the Canyon coal bed and/or overlying aquifers, including alluvium, will be interrupted within and adjacent to mined areas. Wells tapping deeper aquifers should not be adversely affected. Deeper drilled wells can replace interrupted supplies with comparable yields. Water from aquifers underlying the Canyon coal bed is generally a sodium bicarbonate type with dissolved solids content ranging from about 1,000 to 5,000 mg/l. Interrupted supplies generally will be a calcium, magnesium sulfate type with dissolved solids content ranging from about 700 to 1,700 mg/l. Thus, replacement supplies probably will be softer but may contain somewhat more or less dissolved solids than individual interrupted supplies. Replacement supplies should be suitable for most farm-ranch uses.[1/]	Water supplies from wells tapping the Anderson coal bed and/or overlying aquifers and from springs discharging from these aquifers will be interrupted within and adjacent to mined areas. Wells tapping deeper aquifers should not be adversely affected. Deeper drilled wells can replace interrupted supplies with comparable yields, but data for these deeper aquifers are meager and are not definitive. Available data indicate that replacement supplies from deeper aquifers should be approximately equivalent in quality to interrupted supplies. Replacement supplies, therefore, should be suitable for most farm-ranch uses.[1/]	Water supplies from wells tapping the Wall coal bed or the overlying Canyon coal bed and from springs discharging from these aquifers will be interrupted within and adjacent to mined areas. Wells tapping deeper aquifers should not be adversely affected. Deeper drilled wells can replace interrupted supplies with comparable yields at pumping lifts of less than 500 feet. Water from the deeper aquifers should be a sodium bicarbonate type and should contain about the same range of concentration of dissolved solids as water from the Wall and Canyon coal beds. Replacement supplies will be suitable for most farm-ranch uses[1/] but will be inferior in quality to water from the interrupted beds.
What is the probable movement of ground water between aquifers underlying the surface at various depths? Is movement upward or downward? Will contamination result from mining? Is it vertical? What harm could result? What are the expected limits of influence of mining on ground water?	Ground water in the Anderson and Dietz No. 1 coal beds moves toward the Deer Creek Valley and eastward toward the Tongue River. Between the upland north of Deer Creek the water has a downward component of movement toward the Dietz No. 1 coal bed. Extensive contamination of ground water by mining is not expected, except for localized addition of nitrate from blasting. The Miami (1979) reports that, as a result of mining, the water surface in areas near the Decker mine declined more than 10 feet in 1 year to wells more than a mile from the mine.	Movement of ground water is generally downward and laterally from the topographically high areas along the interstream divides toward the valley of Otter Creek, which is a discharge area. Ground-water has an upward component of movement in an area 1 to 2 miles wide along Otter Creek. Movement in the alluvium is generally northward. Ground-water discharge is a primary source of base flow in Otter Creek. Water from coal beds in this area will be of similar quality to water being discharged from wells, springs and seeps. Contamination of existing water supplies, therefore, should not be serious. Appreciable water-level changes caused by mining probably will occur only within 1 to 2 miles of a mine, but the extent of change of water levels and limits of influence cannot be clarified from available data.	Movement of ground water is generally downward and northeastward. Because of the low permeability of the shales that separate the coal beds, however, the amount of water moving downward is small. Water pumped from the coal during mining operations should be of similar quality to water currently discharging from springs in the area. Contamination of existing water supplies, therefore, should not be serious. A mine located near the mouth of Hanging Woman Creek probably will lower water levels appreciably in wells within 4 miles of the mine. A mine further upstream where the Canyon coal bed crosses Otter or Hanging Woman Creek could lower water levels appreciably in wells within 6 miles of the mine.	Movement of ground water is generally downward and laterally from the topographically high areas along the interstream divides toward the valley of Hanging Woman Creek, which is a discharge area. Movement is generally northward in the alluvium along the bottom of Hanging Woman Creek Valley. Permeability of the shale beds separating the aquifers is low, however, and the amount of water moving upward or downward is small. Water pumped from the coal aquifers during mining operations should be of similar quality to water currently being discharged from wells, springs, and seeps in the area. Contamination of existing water supplies, therefore, should not be serious. Mining would increase concentration of nitrate and sulfate in water in Hanging Woman Creek and in the underlying alluvium for several miles downstream from a mine, but no appreciable deterioration in quality is expected.	Movement of ground water is generally downward and southeastward toward the valley of the Tongue River, which is a discharge area. However, some lateral movement is occurring toward Tank and Hell Creeks, which drain southeastward to the Tongue River (fig. 10). Water from coal beds in this area should be of similar quality to water being discharged from wells, springs, and seeps in the area. Contamination of existing water supplies, therefore, should not be serious. Water-level changes caused by a mine between 1 mi and five miles should be limited to the area between these two streams.
What quantities and qualities of ground-water discharge can be expected from mining? Are the quantities small enough to manage? Is the quality expected to be worse than that presently discharging at the surface? How much difference should be expected between spoil-bank leach water and the normally percolating shallow water?	Ground-water discharge from a mine that does not tap alluvium should be comparable to discharge from the Decker mine (less than 0.5 ft³/s). Water from backfill aquifers should contain from about 1,600 to 4,200 mg/l dissolved solids. Principal ions should be sodium, magnesium, and sulfate. Interflow to Deer Creek contains about 4,000 mg/l dissolved solids. Principal ions are calcium, magnesium, and sulfate. Water from spoil materials used for backfill, however, will probably contain higher concentrations of nearly all constituents.	Discharge from a mine in the Knowlton coal bed should be less than 1 ft³/s. The Knowlton bed is nearly saturated along Otter Creek and is completely saturated away from the outcrop. Some inflow from the alluvium may be induced in mines along the outcrop of Otter Creek. Mines in the higher coal beds should produce less than 1 ft³/s. Water from the Knowlton bed should contain magnesium, sodium, sulfate, and bicarbonate as the principal ions. Dissolved solids are expected to range from about 400 to 1,200 mg/l. Water from overlying coal beds and sandstone aquifers should contain magnesium, sodium, sulfate, and/or bicarbonate. Dissolved solids should range from about 400 to 4,700 mg/l. Water from a mine in this area should be of similar quality to water presently discharging from the coal. Composition of the spoil-bank leachate will depend on the character of the overburden. The leachate probably will have a higher concentration of dissolved solids than the water draining from undisturbed areas.	No more than 1 ft³/s can be expected from a mine in this area. Calcium, magnesium, bicarbonate, and sulfate will be major ions in water pumped from mines. Dissolved solids could range from about 200 to locally as high as 7,000 mg/l, but probably will not exceed 5,000 mg/l. Differences between spoil-bank leach water and the normally percolating shallow water should be about the same as in the Deer Creek-Otter Creek area.	No more than 1 ft³/s should be discharged from a mine in this area. Water from a mine in the Anderson or Dietz coal beds should contain about 1,000 to 3,000 mg/l dissolved solids, the principal ions would be sodium, bicarbonate, and sulfate. Mining could produce higher concentrations of sulfate and nitrate, but major changes are not expected. The quantities of water to be pumped are small and should present no serious problem. Spoil-bank leach water probably will be more mineralized than water in the ground water, available data are not adequate to predict precise quality or quantity of the leach water.	A mine between one and 5 mi will likely not discharge more than 1 ft³/s. The effluent will be similar in quality to that currently seeping to the surface, but may contain greater concentration of nitrate. Spoil-bank leachate will be several times more concentrated than the ground water presently being discharged.
After backfilling and reclaiming of mined areas is completed, will water levels in shallow wells return to near the original levels?	If the rubble of mined coal and overburden at the base of the backfill is moderately permeable, water in nearby shallow wells should return to essentially original levels. If the base of the backfill is relatively impermeable, water in nearby shallow wells should attain higher than original levels.				
Can evaporation ponds for leach waters and solid wastes be lined successfully to prevent ground-water deterioration because of contamination by leachates?	No unmanageable problems are anticipated, but special detailed studies are needed to develop engineering techniques for solutions.				

1/ No data are available on concentrations of trace elements in water from the various aquifers in this area.

Table 5.--Preliminary answers to questions posed by Water Work Group

Subareas					
[illegible] ?	Upper Otter Creek Priority areas number 4 and number 4	Hanging Woman Creek Priority area number 5	Cook Creek Priority area number 7	Decker area, North Dakota	Gillette area, Wyoming
[illegible]ping the [illegible]ang [illegible] will be [illegible]ed to mined [illegible]quifers [illegible]ded. Deeper [illegible]rrupted [illegible]lls. Water [illegible]duction [illegible]n bicarb- [illegible]e about the [illegible]of dissolved [illegible]olids. The [illegible]ow, should [illegible]quality for	Water supply from wells tapping the Canyon coal bed and/or overlying aquifers, including Alluvium, will be interrupted within and adjacent to mined areas. Wells tapping deeper aquifers should not be adversely affected. Deeper drilled wells can replace interrupted supplies with comparable yields. Water from aquifers underlying the Canyon coal bed is generally a sodium bicarbonate type with dissolved solids content ranging from about 1,500 to 3,000 mg/l. Interrupted supplies generally will be a calcium, magnesium sulfate type with dissolved solids content ranging from about 370 to 7,700 mg/l. Thus, replacement supplies probably will be softer but may contain somewhat more or less dissolved solids than individual interrupted supplies. Replacement supplies should be suitable for most farm-ranch uses. 2/	Water supplies from wells tapping the Anderson coal bed and/or overlying aquifers and from springs discharging from these aquifers will be interrupted within and adjacent to mined areas. Wells tapping deeper aquifers should not be adversely affected. Deeper drilled wells can replace interrupted supplies with comparable yields, but data for these deeper aquifers are meager and are not definitive. Available data indicate that replacement supplies from deeper aquifers should be approximately equivalent in quality to interrupted supplies. Replacement supplies, therefore, should be suitable for most farm-ranch uses. 2/	Water supplies from wells tapping the Wall coal bed or the overlying Canyon coal bed and from springs discharging from these aquifers will be interrupted within and adjacent to mined areas. Wells tapping deeper aquifers should not be adversely affected. Deeper drilled wells can replace interrupted supplies with comparable yields at pumping lifts of less than 500 feet. Water from the deeper aquifers should be a sodium bicarbonate type and should contain about the same range of concentration of dissolved solids as water from the Wall and Canyon coal beds. Replacement supplies will be suitable for most farm-ranch uses, but will be inferior in quality to water from the clinker beds.	The supply to a few farm-ranch wells will be interrupted within and adjacent to mined areas. Deeper drilled wells can obtain adequate yields from the middle Ludlow, Lower Ludlow-upper Bell Creek, and Basal Bell Creek-Fox Hills aquifers. These aquifers have approximately equivalent transmissivities, water quality is generally better in the Basal Bell Creek-Fox Hills aquifer than in the overlying aquifers, including those affected by mining.	Only the water supply from wells within and adjacent to the mined areas will be interrupted. Wells more than a mile from mined areas will probably be little affected. Comparable yields can be obtained from sandstone aquifers that underlie the coal at depths of less than 500 feet. Water from these deeper aquifers is generally softer and contains less dissolved solids than water obtained from the coal and from shallow aquifers that overlie the coal.
[illegible]nerally [illegible]n top- [illegible]the inter- [illegible]g of Otter [illegible]ons. Ground- [illegible] of movement [illegible]ding Otter [illegible]on is [illegible]otter dis- [illegible] base flow [illegible]al beds in [illegible]quality to [illegible]ble. [illegible]sion of [illegible]efore, [illegible]stable [illegible] mining [illegible]n 2 to 3 [illegible]t of change [illegible] influence [illegible]uable data.	Movement of ground-water is generally downward and northeastward. Because of the low permeability of the strata that separate the coal beds, however, the amount of water moving downward is small. Water pumped from the coal during mining operations should be of similar quality to water currently discharging from springs in the area. Contamination of existing water supplies, therefore, should not be serious. A mine located near the south of Canyon Creek probably will lower water levels appreciably only in wells within a mile of the mine. A mine further upstream where the Canyon coal bed crosses Otter or Canyon Creeks could lower water levels appreciably in wells within 4 miles of the mine.	Movement of ground-water is generally downward and laterally from the topographically high areas along the interstream divides toward the valley of Hanging Woman Creek, which is a discharge area. Movement is generally northward in the alluvium along the bottom of Hanging Woman Creek valley. Permeability of the shale beds separating the aquifers is low, however, and the amount of water moving upward or downward is small. Water pumped from the coal aquifers during mining operations should be of similar quality to water currently being discharged from wells, springs, and seeps in the area. Contamination of existing water supplies, therefore, should not be serious. Mining could increase concentrations of nitrate and sulfate in water in Hanging Woman Creek and in the underlying alluvium for several miles downstream from a mine, but no appreciable deterioration in quality is expected.	Movement of ground-water is generally downward and southeastward toward the valley of the Tongue River, which is a discharge area. However, some lateral movement is occurring toward Cook and Wall Creeks, which drain southeastward to the Tongue River (fig. 19). Water from coal beds in this area should be of similar quality to water being discharged from wells, springs, and seeps. Contamination of existing water supplies, therefore, should not be serious. Mineralized changes caused by a mine between Wall and Cook Creeks should be limited to the area between these two streams.	Vertical movement of ground-water is downward toward the Basal Bell Creek-Fox Hills aquifer, however, intervening confining beds greatly retard downward movement. Most groundwater movement, therefore, is toward discharge areas northeast and southeast of the mine. Contamination of deep aquifers should not be serious. Limits of influence of mining on groundwater levels are not known.	Movement of ground-water is generally from recharge areas south and west of Gillette toward discharge areas in the Belle Fourche River in the southeastern part of the area and in the Little Powder River and its larger tributaries in the northern part of the area. The vertical component of flow is downward in recharge areas and upward in discharge areas. The outcrop area of the Anderson coal bed is in a recharge area. The vertical component of groundwater movement in the areas likely to be mined, therefore, is downward. The horizontal component of movement is generally downdip toward the outcrop area of the coal. Appreciable contamination is not likely to occur. Vertical permeability of the rocks is sufficiently low that the volume of water moving downward is small. Coal beds are currently discharging water as related recharge to the bottom of the larger stream valleys that traverse the upland areas. Thus, coal beds generally are discharging--not absorbing--water in the areas likely to be mined. Contamination of aquifers from mining should occur only in the immediate vicinity of the mined areas and should be amenable to control measures. The effect of mining should be small on aquifers underlying the coal. Wells more than a mile east of mined areas, should not be affected. Wells tapping the coal and/or sandstone aquifers overlying the coal should not be affected significantly more than about a mile from the mined areas.
[illegible]sion [illegible] ft³/s [illegible]ported [illegible]otely [illegible]ng. Some [illegible]be induced [illegible]tter Creek [illegible] should [illegible]ater from [illegible]ddle Fork- [illegible]rbonate [illegible]nd acids [illegible]ent 500 to [illegible]ding coal [illegible]hould con- [illegible]ds, and/or [illegible] should [illegible] mg/l. [illegible]s should be [illegible]ponently [illegible]ompetition [illegible]ill depend [illegible]uration. The [illegible]e higher [illegible]olids than [illegible]ed areas.	No more than 1 ft³/s can be expected from a mine in this area. Calcium, magnesium, bicarbonate, and sulfate will be major ions in water pumped from mines. Dissolved solids could range from about 370 to [illegible] mg/l, but probably will not exceed 1,000 mg/l. Differences between spoil-bank water and the normally fertilizing shallow water should be about the same as in the Lower Otter Creek area.	No more than 1 ft³/s should be discharged from a mine in this area. Water from a mine in the Anderson or Dietz coal beds should contain about 1,000 to 3,000 mg/l dissolved solids, the principal ions should be sodium, bicarbonate, and sulfate. Mining could produce higher concentrations of sulfate and nitrate, but major changes are not expected. The quantities of water to be pumped are small and should present no serious problems. Spoil-bank leach water probably will be more mineralized than other local ground water, available data are not adequate to predict precise quality or quantity of the leach water.	A mine between Cook and Wall Creeks should not discharge more than 1 ft³/s. The effluent will be similar in quality to that currently seeping to the surface, but may contain greater concentrations of nitrate. Spoil-bank leachate will be several times more mineralized than the ground water presently being discharged.	Groundwater discharge from current mining is about 0.2 ft³/s or less, which causes no problems. No change in quality or discharge rates is expected. The water is representative of equivalent quality in Cook Flow is nearly stream. [illegible] conductance of equivalent [illegible] water is expected to range from [illegible] to 4,000 micromhos.	Discharges from most mined areas probably will be less than 1 ft³/s. Water probably will contain about 1,200 to 1,500 mg/l dissolved solids. Dominant ions should be sodium, calcium, magnesium, sulfate, and bicarbonate. The quality of water obtained from the coal and overlying aquifers generally should be better than the quality of water occurring as underflow in the alluvium in the principal stream valleys. Water in the alluvium generally contains about 2,000 to 4,000 mg/l dissolved solids, and the dominant ions are calcium, magnesium, and sulfate. The exception is in the headwater reaches of the Little Powder River where springs discharging from the Anderson coal bed are the principal source of base flow. Water from mining in this part of the area should be essentially the same quality as water in the streams. No data are available on the expected quality of spoil-bank leach water. Spoil banks, however, will contain largely of fine-grained materials derived from strata in the Tongue River Member. Spoil-bank leach water probably will be high in sodium and may contain objectionable amounts of trace elements, including heavy metals, that are not normally present in the shallow ground-water supplies.
If the rubble of mined coal and boulders at the base of the backfill is moderately permeable, water in nearby shallow wells should return to essentially original levels. If the base of the backfill is relatively impermeable, water in nearby shallow wells should stand higher than original levels.					
No intolerable problems are anticipated, but special detailed studies are needed to develop engineering techniques for solutions.					

Table 6.--Record of wells, Oxacoyne and adjacent area, North Dakota

Explanation

Water level: In feet, below or above (+) land surface.
Use of water: H, domestic; K, domestic and livestock; N, industrial; P, public supply; S, livestock; U, unused; I, irrigation.
Major aquifer: 125, Paleocene; 211, Upper Cretaceous; CNBL, Cannonball Member of Fort Union Formation; HCFH, Hell Creek Formation-Fox Hills Sandstone, undifferentiated; LDLW, Ludlow Member of Fort Union Formation; LHCK, Ludlow Member of Fort Union Formation-Hell Creek Formation, undifferentiated; TRVL, Tongue River-Ludlow Members of Fort Union Formation, undifferentiated.
Water-bearing material:
Modifiers: 1, medium grained
Major lithology: 1, lignite; 2, sand

LOCATION NUMBER	DRILLED DEPTH (FT)	WELL DEPTH (FT)	CASING DEPTH (FT)	CASING DIAMETER (IN.)	DATE DRILLED	WATER LEVEL (FT)	DATE WATER LEVEL MEAS.	USE OF WATER	MAJOR AQUIFER	WATER BEARING MATERIAL	SPECIFIC CONDUCTANCE (MICROMHOS)	ICE-MINERAL CONTENT (PPM)	SATURATED THICKNESS OF LUDLOW (FT)
138-097W-7AAAAA	140	140	50	4	1968	--	--	S	--	5	400	9.0	--
139-097W-31CCCC		119	--	4	1950	--	--	K	--	5	700	--	2865
139-097W-31CCC1	179	179	--	4	1962	--	--	H	--	--	3230	--	--
139-097W-31CCC2		170	--	--	1962	--	--	K	--	5	2400	--	2858
139-097W-32ACBB	95	95	--	4	1970	--	--	H	125TRVL	--	1140	--	--
139-098W-04DDBB	1340	1274	1304	8	1971	306	8-71	P	211HCFH	5	1730	22.0	2850
139-098W-05ACCC		1250	--	--	1950	--	--	P	211HCFH	--	1750	19.5	2825
139-098W-07BCCC		170	--	--	1950	--	--	S	--	--	--	--	--
139-098W-07BCD1	70	--	--	4	1964	60	--	S	--	--	1400	9.5	--
139-098W-14CAAA	260	250	--	4	1959	--	--	S	--	--	1400	10.0	--
139-098W-17DAA	246	246	245	4	1961	--	--	S	125LDLW	5	1940	10.0	--
139-098W-24AAA		82	--	5	1968	65	--	K	--	--	700	--	2820
139-098W-34ABC	63	58	44	4	1972	18	--	S	--	5	--	--	--
139-098W-35CCC		125	--	--	1966	--	--	H	--	--	1400	--	--
139-098W-36AAB	63	58	54	4	1962	--	--	H	--	P	3500	--	--
139-098W-36CCB		163	35	5	1953	--	--	K	125LDLW	5	2600	--	2760
139-099W-13ADD		--	--	--	--	42	--	S	--	--	712	11.0	2780
139-099W-19BAA	410	396	376	12	1972	83	8-72	U	125LHCK	5	1610	11.0	2775
139-099W-19BAA2	200	198	142	24	1972	83	8-72	U	125LDLW	5	2280	--	2775
139-099W-19BCB		170	--	4	1950	--	--	H	--	--	1559	--	2780
139-099W-19BCB	181	178	164	4	1960	125	--	S	125LDLW	15	--	--	2810
139-099W-24AAD		28	--	18	1950	12	--	K	--	5	7100	--	--
139-100W-19AAA	400	418	408	12	1972	112	7-72	U	125LHCK	5	1580	11.0	2815
139-100W-20BCC	103	76	--	4	1963	62	--	H	--	--	1480	--	--
139-100W-20DAA	157	157	--	5	1959	--	--	U	--	--	--	--	--
139-100W-20DBA	135	129	130	6	1973	0	--	K	125TRVL	5	2810	10.0	--
139-100W-21AAA		140	100	5	1951	40	--	K	--	--	--	--	--
139-100W-21CCC	145	74	139	--	1972	80	--	--	--	5	1958	--	--
139-100W-21DDD1		118	--	4	1947	110	--	H	125TRVL	5	1400	--	--
139-100W-27CCC1	200	--	--	--	1974	--	--	S	--	--	--	--	--
139-100W-27CCC2		135	125	6	1970	--	--	H	--	--	1000	--	--
139-100W-28BCCA	240	--	--	--	--	--	--	U	--	--	--	--	--
139-100W-31AAA	117	113	--	5	1951	--	--	H	125TRVL	5	900	--	--
139-100W-31BCC	110	110	--	--	1968	--	--	U	125TRVL	--	--	--	--
139-100W-33BCC1	180	171	90	4	1970	14	4-71	U	125TRVL	5	--	--	--
139-100W-33CCA	91	83	69	4	1970	50	--	H	125TRVL	5	1080	--	--
139-101W-24CCC	367	313	--	4	1963	190	--	K	125CNBL	--	1460	9.0	2930
139-101W-25AAA		370	--	4	1910	156	--	K	125TRVL	1	2070	--	--
139-101W-25CCC	96	95	77	4	1963	--	--	S	125TRVL	5	950	9.0	--
139-101W-26AAA		70	--	6	1955	--	--	K	125TRVL	5	2100	11.0	--
139-101W-26CCC		140	140	6	--	--	--	K	--	5	1853	--	--
139-101W-27AAA	400	356	388	12	1972	121	7-72	U	125CNBL	5	1760	10.0	2882
139-101W-27CCC	1001	248	947	12	1972	138	7-72	U	125TRVL	5	1630	9.0	2887
139-101W-28AAA		170	90	6	1950	76	--	U	125TRVL	5	500	--	--
139-101W-28CCC		60	60	6	1950	40	--	K	--	1	1150	--	--
139-101W-34CCB	70	70	--	4	1956	14	--	S	125TRVL	--	--	--	--
139-102W-19CCC		190	--	4	1961	--	--	K	125TRVL	1	1950	--	2950
139-102W-20CCC	61	53	--	4	1972	15	--	S	--	5	1955	--	--
139-102W-21CCC		80	--	4	1910	60	--	K	125TRVL	--	1600	--	2940
139-102W-22CCC		60	45	4	1947	40	--	H	125TRVL	--	1700	--	2960
139-102W-28AAA		375	315	--	1970	80	--	H	125LDLW	5	1500	--	2865
139-103W-23CCC1	142	110	--	--	--	50	--	S	125TRVL	1	2250	16.0	2945
139-103W-23CCC2	360	356	--	6	--	--	--	U	125LDLW	5	1480	17.0	2945
139-103W-34CAB	1365	1254	--	4	1971	156	--	S	211HCFH	5	--	--	2760
139-104W-12BAA		90	--	4	--	--	--	S	125TRVL	1	2310	--	--
139-104W-24AAA		140	--	4	--	20	--	S	--	5	1450	--	2830
139-105W-23DAD	133	--	--	4	1956	30	--	I	--	--	--	--	--
141-100W-23DAA		1100	--	--	1936	--	--	P	211HCFH	--	1860	19.5	--
141-100W-34DDD	124	--	--	6	1950	--	--	U	--	--	--	--	--
141-100W-34AAA	100	73	--	4	1958	50	--	K	125TRVL	1	1950	--	--
141-101W-16AAA	1200	1193	1180	--	1969	--	--	K	211HCFH	5	1860	16.0	2779
141-101W-21CAA1	1300	1240	--	--	1971	145	7-71	U	211HCFH	--	1740	20.0	2845
141-101W-21CAA2	420	393	376	2	1971	97	8-71	U	125LHCK	--	2110	9.5	2845
141-101W-21CAB1	230	224	217	3	1971	16	8-71	U	125LDLW	--	2500	7.0	2845
141-101W-21CAB2	90	83	124	02	1972	7	7-72	U	125LDLW	--	2500	11.0	2845
141-101W-21CAC	140	140	140	4	1972	90	--	U	--	5	1660	--	--
141-101W-21CAD	77	--	--	6	--	--	--	S	125TRVL	5	2200	7.0	--
141-101W-28AAA		84	74	5	1967	--	--	H	125TRVL	--	1900	--	--
141-101W-28CAB		2160	160	5	1964	45	--	S	125TRVL	--	1690	10.0	--
141-101W-31AA		40	--	5	1968	--	--	H	125TRVL	1	1850	--	--
141-101W-34CAC	92	91	90	4	1962	15	--	K	125TRVL	5	1980	--	--
141-102W-13CCB		74	--	6	--	--	--	H	125TRVL	5	2200	--	--
141-102W-19CCC1	150	150	--	6	--	--	--	K	125TRVL	5	2150	14.0	--
141-102W-21CAB	115	115	90	5	1960	--	--	S	125TRVL	5	1750	--	--
141-102W-21CAC	96	--	--	4	1969	--	--	H	125TRVL	5	1730	--	--
141-102W-28AAA		70	--	5	--	--	--	K	125TRVL	5	2100	--	--
141-102W-31CCC		90	--	4	1964	61	--	K	125TRVL	5	2000	--	--
141-102W-34CCC		70	64	24	1957	50	--	K	125TRVL	5	2950	--	--
141-103W-24CCC	100	64	--	--	--	45	--	U	125LDLW	--	--	--	--
141-103W-31CAC		150	--	4	1955	75	--	H	125TRVL	--	1400	--	2814
141-103W-34CCC	1335	--	--	--	1968	--	--	U	--	--	--	--	2866
141-104W-13CCC1	660	572	540	2	1971	265	10-71	U	125LHCK	--	2600	11.0	2900
141-104W-13CCC2	110	110	104	1	1971	71	10-71	U	125TRVL	--	1150	9.5	2900
141-104W-14CBC		112	--	6	1958	70	--	K	125TRVL	5	2550	12.0	2883
141-104W-14CCA	60	51	--	4	1954	40	--	S	125TRVL	--	2240	9.0	--
141-104W-23CCC		1200	1150	--	1955	241	9-70	H	211HCFH	5	1810	12.0	2904

Table 7.--Chemical analyses of water from wells in Hascoyne area, North Dakota

(Constituents in milligrams per liter except as indicated)

Local identifier	Geologic unit 1/	Total depth of well (feet)	Date of sample	Dissolved silica (SiO_2)	Dissolved iron (Fe) 2/	Dissolved Manganese (Mn) 2/	Dissolved Calcium (Ca)	Dissolved Magnesium (Mg)	Dissolved Sodium (Na)	Dissolved Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Dissolved Sulfate (SO_4)	Dissolved Chloride (Cl)	Dissolved Fluoride (F)	Dissolved Nitrate (NO_3)	Dissolved Boron (B) 2/	Dissolved solids (residue at 180°C)	Hardness (Ca,Mg)	Noncarbonate hardness	Percent Sodium	Sodium adsorption ratio	Specific conductance (micromhos)	pH (units)	Temperature (deg C)
130N098W04CBB	125TRVL	65	71-06-30	5.4	0	30	59	31	160	11	410	0	470	4.5	.3	2.5	900	768	170	0	54	4.2	1140	7.7	--
130N098W04DBB	211HCFH	1274	71-10-11	10	0	10	3.4	1.6	410	1.9	900	0	11	130	4.9	1.0	1500	1040	15	0	90	47	1730	8.2	22.0
130N098W04ECC	211HCFH	1200	70-07-13	11	140	20	220	1.5	490	3.1	990	4	4.1	140	4.6	1.0	1400	1750	11	0	99	57	1760	8.2	19.5
130N099W17DAA	125LGLW	296	71-08-30	8.4	930	20	6.3	7.4	662	4.1	980	15	300	6.9	7.6	.00	1000	1180	51	0	95	29	1940	8.4	10.0
130N099W19BCC	--	--	70-07-13	11	100	10	41	19	200	5.3	360	0	79	3.5	1.6	1.0	30	455	150	0	--	3.6	712	7.9	11.0
130N099W17AAA2	125LAKV	348	71-08-29	7.0	.20	10	15	6.7	400	2.5	700	40	220	4.6	6.7	5.5	710	1020	65	0	93	22	1610	8.7	11.0
130N099W17AAA3	125LGLW	298	71-08-29	5.8	0	10	57	24	500	5.0	600	22	720	7.0	4.9	1.0	40	1610	260	0	86	17	2280	8.5	14.0
130N100W01AAA	125LAKV	420	70-07-05	5.8	190	30	31	9.9	400	1.7	700	41	250	4.4	5.3	2.0	890	1380	64	0	93	22	1560	8.8	11.5
130N100W01CAA/	125TRVL	224	71-08-24	7.9	430	20	61	7.1	650	3.6	720	0	470	11	3.8	1.0	730	1950	74	0	95	33	2810	8.2	10.0
131N098W01BCC4	125TRVL	51	71-06-15	7.6	70	30	17	4.6	340	5.8	440	0	460	6.8	1.0	.00	1600	1040	62	0	89	16	1560	8.0	--
131N098W07BCC	125CNBL	351	71-06-15	4.9	530	20	7.9	7.9	380	2.6	460	18	85	17	5.9	.30	640	935	52	0	94	23	1440	8.5	9.5
131N098W08CDD	125TRVL	170	71-06-15	15	8400	190	130	100	230	16	880	0	540	8.0	.1	1.0	1900	1470	760	30	39	3.6	2030	7.4	--
131N098W23DAD1	125CNBL	356	71-06-21	9.6	40	20	19	16	430	1.9	640	24	430	1.1	5.5	4.0	680	1260	100	0	89	18	1760	8.6	10.5
131N098W23DAD2	125TRVL	246	71-06-21	6.7	0	20	21	11	390	2.7	570	0	440	4.6	3.4	.90	540	1240	96	0	89	17	1610	8.2	9.5
131N099W04DAA	125TRVL	390	71-04-14	9.1	1700	30	6.8	4.9	360	1.5	770	12	150	6.3	3.4	.10	1200	953	37	0	95	26	1450	8.3	--
131N099W22CCC1	125TRVL	112	70-08-11	7.9	1600	60	7.2	3.4	520	5.6	600	0	670	5.8	4.2	1.0	770	1470	32	--	97	40	2260	8.1	10.0
131N099W22CCC2	125LGLW	138	70-08-11	9.0	320	10	7.1	.6	530	2.0	1200	17	48	7.2	19	2.0	1100	1170	8	0	99	77	1980	8.4	13.0
131N100W23DBA	211HCFH	1180	70-07-20	12	300	10	2.1	.7	420	1.5	790	3	190	35	3.8	1.0	1300	997	7	0	99	68	1660	8.2	19.5
131N100W24ABB	125TRVL	71	70-08-14	9.4	100	50	45	15	200	7.0	450	0	190	7.7	2.5	1.0	630	643	1.0	0	76	7.7	1050	8.2	--
131N100W26ABA	211HCFH	1193	72-02-24	11	410	20	3.6	2.4	440	1.7	780	45	93	120	3.0	1.0	1000	1080	19	0	98	43	1870	8.8	6.0
132N097W07CAB1	211HCFH	1080	71-07-29	12	2800	30	5.2	1.5	450	1.7	880	0	180	54	5.3	1.0	1600	1110	19	0	98	45	1790	8.0	20.0
132N097W07CAB2	125LAKV	590	71-10-28	7.7	0	40	8.4	3.6	550	3.4	1250	33	140	15	6.5	1.0	1800	1430	38	0	97	40	2210	8.4	9.3
132N097W07CAB3	125LGLW	229	71-10-29	9.8	1100	30	26	2.4	370	2.5	880	25	100	49	5.5	1.0	1200	1010	75	0	91	19	1500	8.5	7.5
132N097W07CAB4	125LGLW	335	72-06-20	7.7	620	10	2.2	.9	540	2.1	1340	53	14	7.6	6.1	1.0	1300	1310	9	0	99	78	2050	8.7	11.0
132N098W23CDD	125TRVL	150	71-08-06	6.1	4100	60	1.0	23	530	4.9	680	0	660	2.5	1.3	.00	460	1640	39	[illegible]	92	23	2340	8.2	14.0
132N099W32DDC1	125LAKV	572	71-10-11	9.1	2500	20	18	30	600	3.3	950	41	600	15	8.7	1.0	1100	1700	170	0	88	19	2600	8.7	11.0
132N099W32DDC2	125TRVL	110	71-09-11	15	500	80	92	61	79	7.5	440	0	290	3.2	.4	5.0	0	753	490	120	26	1.6	1130	8.0	8.5
132N100W14ADB	125TRVL	51	70-08-14	7.5	180	20	32	11	500	4.9	630	6	670	3.6	2.3	1.0	300	1500	130	0	89	20	2280	8.3	9.0
132N100W35DDD	211HCFH	1200	70-08-18	12	0	10	4.1	1.2	450	1.3	910	0	180	37	4.0	.00	1100	1130	15	0	98	50	1810	8.2	--

1/ 125, Paleocene; 211, Upper Cretaceous; CNBL, Cannonball Member of Fort Union Formation; HCFH, Hell Creek Formation-Fox Hills Sandstone, undifferentiated; LaLe, Ludlow Member of Fort Union Formation; LAKE, Ludlow Member of Fort Union Formation-Hell Creek Formation, undifferentiated; TRVL, Tongue River-Ludlow Members of Fort Union Formation, undifferentiated.

2/ Reported in micrograms per liter.

Table 8.--Record of selected wells, springs, and oil and gas test holes in the eastern Powder River Basin and adjacent areas, northeastern Wyoming

Location	County	Year drilled	Altitude of land surface above mean sea level (feet)	Depth of well below land surface (feet)	Distance to water below land surface (feet) 1/	Diameter of well (inches)	Use of water 2/	Geologic source	Discharge or flow (gallons per minute) 1/	Drawdown (feet below non-pumping water level) 1/	Date of measurement (mo - yr)
33N72W7DB	Converse	1943	4880	12	8	2	D	Alluvium	--	--	7-31
33N81W33DD	Natrona	1948	5278	42	17M	6	S,D	Alluvium	--	--	7-50
34N77W9BC	Natrona	--	5384	90	12	6 5/8	S	Lance Formation	--	--	11-65
35N60W27BA	Niobrara	1945	--	15	13M	48	S,D	Alluvium	5	4.4	11-59
35N65W9CC	Niobrara	--	--	11	6M	--	P	Alluvium	16	2	11-59
35N70W4BA	Converse	1946	--	415	Flowing	4	S	Fort Union Formation	.6M	--	6-69
36N65W14DB	Niobrara	1940	--	73	45	6	S,D	Lance Formation	5	--	11-59
36N75W9CC	Converse	--	--	360	210	4	In	Fort Union Formation	--	--	--
38N62W17AA	Niobrara	--	--	110	1M	6	D	Fox Hills Sandstone	--	--	10-59
38N63W23DC	Niobrara	--	--	105	45	6	S,D	Fox Hills Sandstone	5	--	3-60
39N65W21CC	Niobrara	1951	--	280	70	5	S	Lance Formation	5	--	--
39N66W10AA	Niobrara	--	--	132	109	--	--	Fort Union Formation	--	--	--
39N72W6BD	Converse	1968	--	1104	Flowing	2	S	Fort Union Formation	24	--	6-68
40N73W8CD	Converse	1937	4836	310	Flowing	2	S	Wasatch Formation	5.5M	--	7-69
40N78W11AC	Natrona	1961	5120	950	62	8 5/8	N	Fox Hills Sandstone	22	249	6-63
26CB	Natrona	--	5030	90	60	7 1/2	D	Fox Hills Sandstone	--	--	--
41N63W14AA	Weston	--	--	180	140	6	S	Lance Formation	--	--	--
41N80W22AC	Johnson	1955	4810	1150	Flowing	22	S	Frontier Formation	10	--	--
42N65W6CA	Weston	1960	--	2259	150	13	In,W	Fox Hills Sandstone	47	200	8-60
30BC	Weston	1968	--	114	50	7	S	Lance Formation	30	.5	10-68
42N67W14AC	Weston	1965	--	161	60	6	S	Fort Union Formation	30	40	8-65
42N70W5DD	Campbell	1966	--	233	110	6	S	Wasatch Formation	10	30	--
42N77W24CA	Johnson	1960	--	5530	Flowing	2	S	Wasatch Formation	6	--	12-60
42N78W15CA	Johnson	--	5280	630	184	6 7/8	S	Lance Formation	3.5M	--	8-69
43N80W20CC	Johnson	--	--	140	17	4	D	Fox Hills Sandstone	--	--	--
20CC	Johnson	--	4498	16	8M	24	S	Alluvium	--	--	9-50
43N82W12AC	Johnson	1950	4647	17	6M	60	P	Alluvium	--	--	8-50
44N82W17DD	Johnson	--	--	12	7M	60	D	Alluvium	--	--	8-69
45N79W20BD	Johnson	1966	4679	4760	2156	--	W	Lance Formation	124	1008	3-69
45N81W18DB	Johnson	1956	5060	200	128	4	S	Lance Formation	--	--	--
46N64W20BB	Weston	1964	--	200	159	4	S,D	Fox Hills Sandstone	--	--	--
46N72W1BC	Campbell	1954	--	90	30M	4	S	Wasatch Formation	--	--	7-68
46N73W34CC	Campbell	1965	--	200	19M	6	D	Wasatch Formation	20M	30M	7-68
47N67W28A	Weston	1947	--	160	60	6 5/8	S,D	Lance Formation	3	--	--
48N68W26BA	Weston	1967	4490	2250	325	6	W	Fox Hills Sandstone	105	--	--
48N69W28DC	Campbell	1954	--	40	15M	7	S	Alluvium	--	--	7-68
49N72W5AA	Campbell	--	--	120	55M	6	S	Wasatch Formation	--	--	5-49
49N77W20BA	Johnson	1960	3935	31	7M	16	In	Alluvium	60M	--	4-61
50N68W14DD	Crook	1955	--	97	14M	8	S	Lance Formation	4.4M	28.6	6-56
50N72W8BB	Campbell	--	--	360	160	6	S,D	Wasatch Formation	--	--	5-49
20CA	Campbell	1909	4607	160	--	6	S,D	Wasatch Formation	--	--	--
21AC	Campbell	1948	--	210	--	8	--	Wasatch Formation	40	--	--
51N69W20BD	Campbell	1957	--	206	--	4	S,D	Fort Union Formation	--	--	--
20DB	Campbell	1966	4147	2250	Flowing	8	S	Fox Hills Sandstone	.5	--	7-68
51N72W22CB	Campbell	1957	--	1000	32M	8	S	Wasatch Formation	--	--	8-68
52N70W20C	Campbell	1969	3926	2164	--	10 3/4	In	Fox Hills Sandstone	1688	345	--
52N77W3AB	Johnson	1947	--	828	Flowing	4	S	Fort Union Formation	17.0	--	11-59
53N73W24AC	Campbell	1957	--	173	50	4	S	Fort Union Formation	18	--	5-57
53N83W7DD	Sheridan	1959	--	42	7M	4	--	Wasatch Formation	30	10	5-61
54N65W13BA	Crook	1953	--	38	8M	16	I	Alluvium	266M	18.3M	7-46
54N79W21BD	Sheridan	--	--	121	--	8	P	Wasatch Formation	8	--	--
56N70W34BD	Campbell	1959	--	580	Flowing	2	S	Fort Union Formation	16	--	7-68
56N78W22AC	Sheridan	1954	--	165	Flowing	4	S	Fort Union Formation	1M	--	8-60
57N71W14BD	Campbell	1960	--	615	Flowing	2	S	Fort Union Formation	.5	--	8-68
57N74W18DA	Campbell	1966	--	400	240M	6	S	Fort Union Formation	10M	10M	8-68
57N74W34BB	Sheridan	1950	--	315	Flowing	6	S,D	Lance Formation	175M	--	9-69
58N69W31CC	Campbell	1954	--	625	Flowing	4	S	Fox Hills Sandstone	8	--	10-68

1/ M, measured.

2/ Use of water: D, domestic; S, stock; In, industrial; I, irrigation; W, water flood for secondary recovery in oil fields; P, public supply.

Table [illegible].--Chemical analyses of water from selected water wells, Powder River basin, Wyoming.
(Mineral constituents and hardness in milligrams per liter; boron in micrograms per liter.)

Location	Aquifer	Well depth or interval sampled (feet)	Date of sample	Temperature (°C)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (Sum of constituents)	Hardness (Ca,Mg)	Specific conductance (micromhos)	pH (units)	County
33N/72W 7DB	Alluvium	11	8-17-50	12.0	17	140	33	390	6.8	510	0	700	31	.6	2.3	420	1510	480	2120	7.8	Converse
/38N/77W 30B	" "	20	8-25-47	12.0	16	140	44	250	3.7	330	0	740	32	.7	.0	100	1380	530	1900	7.7	Natrona
33N/81W 33DD	" "	42	6-14-44	14.0	13	410	740	1100	13	360	0	5300	120	1.1	207	700	8240	4000	8280	7.8	"
34N/80W 30AD	" "	11	6-13-47	12.0	26	140	62	250	11	430	0	600	44	2.0	32	510	1290	660	1740	7.6	"
35N/60W 27BA	" "	15	11-12-59	-----	29	94	22	180	17	430	0	350	24	.4	.5	290	915	330	1330	7.1	Niobrara
35N/65W 3CC	" "	11	11-11-59	-----	22	100	31	230	15	420	0	500	19	.5	.4	290	1120	380	1610	7.1	"
43N/80W 29CC	" "	16	8-19-50	10.0	16	140	69	220	7.5	330	0	670	120	.4	2.6	100	1400	630	1880	7.4	Johnson
43N/82W 12AJ	" "	17	9-22-50	14.0	12	170	58	150	6.4	270	0	610	110	.4	.9	100	1250	670	1670	7.4	"
44N/82W 17DD	" "	12	8-12-49	-----	13	290	95	290	5.8	370	0	710	58	.3	.1	140	1550	1180	2330	8.1	"
49N/69W 28DC	" "	40	7- 2-48	-----	13	84	23	58	4.7	390	24	74	1.4	.4	.1	80	467	300	753	8.5	Campbell
49N/77W 20BA	" "	11	10-27-48	12.0	11	300	87	290	8.5	270	0	1200	190	.4	.8	210	2240	1100	2860	7.4	Johnson
54N/81W 13BA	" "	30	10-18-56	9.0	19	160	73	27	6.8	300	0	970	3.5	.5	.0	260	1670	1200	1940	7.2	Crook
40N/73W 8CD	Wasatch Fm	310	7- 1-49	13.0	12	30	4.1	160	2.1	190	0	280	3.5	.2	.2	40	587	92	901	7.8	Converse
42N/70W 5DD	" "	233	7- 9-48	12.0	37	410	920	720	6.8	250	0	5900	35	1.0	.2	60	8200	4800	7660	8.1	Campbell
42N/77W 24CA	" "	530	8-22-49	14.0	10	10	2.2	120	2.6	200	1	110	4.4	.6	0	70	358	34	579	8.4	Johnson
46N/72W 1BC	" "	90	7-15-48	11.0	12	590	220	170	14	390	0	2500	19	1.9	1.8	110	3660	2400	3600	8.2	Campbell
46N/73W 34CC	" "	290	7-19-48	12.0	8.8	130	31	270	4.9	570	0	560	12	.3	1.2	50	1300	450	1820	8.1	"
49N/72W 5AA	" "	120	6-14-49	-----	12	880	110	40	9.2	66	0	1400	6.0	.6	4.6	270	1940	1400	2210	7.0	"
50N/72W 8BB	" "	380	5-20-49	11.0	12	25	14	250	5.6	820	0	2.4	6.0	.8	.8	80	734	120	1180	7.5	"
50N/72W 20CA	" "	160	5-21-49	-----	17	85	32	9.1	5.6	250	0	150	4.0	.9	2.4	0	430	340	647	7.6	"
50N/72W 21AC	" "	210	6- 7-47	11.0	19	150	130	34	9.9	320	0	910	9.6	.7	.2	110	1520	1170	1960	7.2	"
51N/72W 22CB	" "	190	6- 6-46	12.0	12	79	38	310	10	1120	0	73	1.2	.7	.0	360	1070	350	1660	7.5	"
53N/79W 7DD	" "	42	8-28-41	14.0	13	34	11	2.3	1.0	160	0	1.3	.3	.2	.5	10	141	130	248	7.8	Sheridan
54N/79W 21BD	" "	121	10-26-40	11.0	8.8	30	5.1	320	1.9	730	0	140	2.8	.9	.1	110	860	72	1400	8.1	"
35N/70W 4BA	Ft. Union Fm	415	6-19-49	14.0	9.2	9.8	.4	160	2.0	310	0	100	8.0	1.5	2.7	40	446	26	906	8.1	Converse
36N/75W 8CC	" "	360	9-29-49	11.0	27	60	11	5.7	3.6	94	0	75	1.6	.5	4.4	20	215	160	326	8.9	"
39N/64W 10AA	" "	132	12- 1-59	2.0	12	150	73	330	8.2	810	0	780	8.8	0	11	90	1770	680	2380	7.8	Niobrara
39N/72W 6BD	" "	1104	6-17-48	19.0	11	9.3	.5	94	1.4	170	4	81	2.8	.2	.1	50	286	25	458	8.4	Converse
42N/67W 14AC	" "	161	9- 9-49	12.0	7.0	4.8	4.4	380	1.9	940	9	33	30	2.2	3.8	70	942	30	1610	8.3	Weston
51N/69W 29BD	" "	206	7- 1-48	----	6.9	28	3.9	450	4.9	580	22	530	1.5	2.8	9.0	180	1340	86	1980	8.7	Campbell
52N/77W 3AB	" "	828	10-26-40	17.0	11	14	3.4	500	4.6	1350	0	1.5	28	.6	0	70	1220	49	1900	8.0	Johnson
53N/73W 24AC	" "	173	5-14-48	12.0	7.6	380	230	430	17	1350	0	1100	9.3	.7	4.9	30	2740	1400	3430	7.5	Campbell
54N/70W 34BC	" "	580	7-10-48	14.0	8.7	2.9	.7	300	1.5	510	12	210	6.1	.7	.0	190	792	10	1230	8.5	"
54N/78W 22AC	" "	164	8-30-41	15.0	9.2	7.3	2.9	400	3.5	1110	0	2.3	7.4	2.2	.0	150	981	30	1570	8.2	Sheridan
57N/71W 14BC	" "	615	8- 8-40	13.0	9.6	2.3	.9	250	1.1	470	24	130	5.6	2.3	.2	130	681	9	1360	8.8	Campbell
57N/74W 18DA	" "	400	8- 1-40	13.0	7.1	440	320	890	21	730	12	3600	10	.2	.2	330	5820	2400	5990	8.3	"
34N/77W 9BC	Lance Fm	90	11-10-65	10.0	15	170	97	78	9.2	300	0	710	37	.7	.0	60	1170	834	1710	7.8	Natrona
36N/65W 14DB	" "	73	12- 2-59	-----	15	89	30	220	12	380	0	390	80	.5	.4	230	1030	347	1540	7.9	Niobrara
39N/65W 21CC	" "	280	12- 1-59	7.0	27	47	3.5	920	4.0	680	5	1500	15	.2	13	140	2850	132	3440	7.6	"
41N/63W 15AA	" "	280	9-12-49	-----	22	11	.6	710	2.0	790	11	700	9.0	.6	9.2	210	1960	32	2900	8.4	Weston
42N/65W 36BC	" "	214	9- 9-49	12.0	9.0	70	28	130	1.9	449	4	160	13	.4	13	70	670	292	1010	8.3	"
42N/78W 14CA	" "	630	9-12-49	20.0	4.4	12	9.5	680	1.8	310	10	770	5.0	.9	.2	280	1450	69	2110	8.7	Johnson
45N/79W 20BB	" "	4760	8- 7-49	42.0	18	0.5	1.6	190	4.7	320	4	140	18	1.8	.0	210	566	36	854	8.4	"
45N/81W 14DB	" "	200	8-25-49	10.0	12	59	14	0.5	2.4	230	0	33	1.6	.5	6.8	90	251	200	412	8.1	"
47N/67W 2BA	" "	160	7-15-49	11.0	8.3	13	4.0	466	2.3	450	0	640	4.0	.1	.2	150	1340	57	2030	8.2	Weston
52N/68W 9ACD	" "	97	8-16-56	10.0	6.7	11	4.2	320	1.6	590	0	280	10	.8	.1	230	900	53	1440	8.2	Crook
57N/86W 34BB	" "	325	8-28-51	12.0	0.4	33	18	400	5.1	590	0	490	42	.3	.3	190	1300	160	1970	8.0	Sheridan
36N/62W 17AA	(Fox Hills Sandstone)	105	12- 1-59	7.0	8.0	14	3.2	1000	2.9	380	0	1900	23	.6	.2	480	3250	48	4445	7.8	Niobrara
36N/63W 23DC	" "	105	12- 1-59	6.0	9.8	37	13	600	4.5	380	0	1120	11	.7	2.6	310	1980	140	2780	7.9	"
40N/78W 11BC	" " 1/	950	5-24-63	13.0	7.4	29	2.3	370	6 1/	450	0	480	13	1.4	1.7	---	1130	92	1790	8.0	Natrona
40N/78W 24CB	" "	90	7-13-47	16.0	7.9	20	1.0	660	2.0	470	0	1190	12	.8	.9	120	2000	54	2950	7.9	"
41N/65W 6CA	" "	2259	7-12-49	25.0	11	3.8	.6	350	1.0	560	0	290	11	2.5	.2	210	943	12	1490	8.1	Weston
42N/80W 29CC	" " 1/	140	8-19-50	11.0	13	320	120	780	8.0	440	0	2300	160	.4	.2	100	3930	1300	4570	7.4	Johnson
46N/64W 20BB	" "	200	10-23-48	----	12	67	16	82	4.2	370	0	160	0.5	.2	.0	110	579	220	875	8.0	Weston
49N/68W 26BA	" "	2250	7-17-49	25.0	12	1.5	.8	330	1.0	620	26	310	11	.9	.0	170	950	7	1400	9.0	"
51N/69W 20DB	" "	2250	7- 1-48	10.0	8.0	18	1.2	390	3.8	560	20	260	3.5	1.8	4.9	120	1110	50	1660	8.7	Campbell
52N/70W 2DC	" "	2144	8-27-72	----	----	0	0	340	C 1/	520	38	200	33	3.1	0	---	837	----	----	8.6	"
52N/69W 31CC	" "	625	10- 8-48	12.0	11	4.6	.4	232	1.2	310	0	270	2.1	.1	.1	30	676	18	1040	8.2	"

1/ C, Potassium (K) and sodium (Na) were calculated together and recorded in sodium column.
2/ Some water also from Lance Formation.

Table 10.--Table of selected wells in Gillette area, Wyoming

Location number: See text for description of well-numbering system.
Depth of well: Measured well depth, to nearest foot.
Depth to water below land surface: Depth to water below top of casing to nearest 0.1 foot.
Altitude of land surface: Altitude of land surface at well, estimated from U.S. Geological Survey 7½ minute quadrangle topographic maps; accurate to 10 feet.
Date of measurement: Day, month, and year of measurement.
Conductivity: Electrical conductance of water, in micromhos per centimeter at 25°C.

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement	Conductivity	Temperature °C	Remarks
46N70W5BBC	144	84.4	4,542	5-31-73	2,000	13.5	
46N70W10DAD	92	25.9	4,655	6- 6-73	350	11.5	
47N68W30CDB	136	36.0	4,475	6- 5-73	1,350	11.0	
47N69W1BCC	88	83.7	4,405	6- 5-73			Well probably caved, pump was hard to raise, as if it were buried in mud
47N69W2CAD	174	133.4	4,460	6- 5-73	1,875	12.0	
47N69W13BDC	128	52.6	4,474	6- 5-73	340	11.5	
47N69W18ADC	196	133.6	4,492	6- 1-73	2,000	14.0	
47N69W19ACD	177	115.2	4,490	6- 1-73			
47N69W21DDA	207	82.8	4,465	6- 1-73	1,875	11.5	
47N69W32BDD	197	52.5	4,575	6- 1-73	850	12.0	Water level measured below bottom of hole in side of casing
47N69W35ABA	314	178.4	4,607	6- 5-73	2,175	12.0	
47N70W2AAC	134	63.7	4,403	6- 1-73	825	13.5	
47N70W3BBA	98	43.0	4,402	5-31-73	1,025	12.0	
47N70W4ABC	247	1.0	4,383	5-31-73	625	17.5	
47N70W7BDB	192	142.7	4,566	5-31-73	1,525	13.5	Depth measurement uncertain

Table 10.--Table of selected wells in Gillette area, Wyoming--continued

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement	Conductivity	Temperature °C	Remarks
47N71W1CAA	106	69.8	4,514	5-31-73	2,900	10.5	
47N71W4CDC	190	90.1	4,585	5-14-73	3,600	11.5	
47N71W7CCC	115	61.6	4,600	5-14-73	1,825	11.0	Well was pumping on arrival. Shut pump off; after 30 minutes water level still rising slowly
47N71W9CCC	120	51.6	4,650	5-31-73	1,650	12.0	
47N71W11CAC		38.0	4,687	5-31-73	4,000	11.5	
47N71W13DDB	155	82.6	4,525	5-31-73	2,900	11.5	Depth measurement uncertain
47N71W15ACB	322	206.2	4,648	6- 6-73	1,050	16.0	
47N71W16BCA	98	81.9	4,685	5-14-73	460	11.5	
47N71W21CDB	122	68.6	4,655	5-14-73	950	12.0	
47N71W22CAC	23	12.7	4,610	6- 1-73			
47N71W23BCC	15	8.2	4,545	5-31-73	1,875	11.0	
47N71W23DCC	113	55.5	4,525	5-31-73	2,000	13.5	
47N71W24DDD	136	86.3	4,530	5-31-73	2,175	14.0	
47N71W30DBB	69	50.1	4,668	5-14-73	2,900	10.5	
47N71W34BCD	79	23.9	4,580	5-14-73	825	12.0	
47N72W2ADA	64	9.6	4,525	5-14-73	6,000	9.0	
47N72W15AAD	55	19.3	4,610	5-13-73	1,700		
47N72W16BAD	49	23.6	4,635	5-13-73	1,050	10.0	
47N72W20BDB	309	171.6	4,837	5-13-73	2,700	11.5	
47N72W26CAD	148	124.6	4,765	5-14-73	2,000	12.0	
47N73W1CB	147	13.2	4,722	5-13-73	5,500	10.0	
47N73W3BAA		15.7	4,725	5-30-73	1,775	10.0	
47N73W6DAA	51	21.8	4,800	5- 9-73	2,250	9.5	

Table 10.--Table of selected wells in Gillette area, Wyoming--continued

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement	Conductivity	Temperature °C	Remarks
47N73W15CAA	202	81.6	4,795	5-10-73	2,700		Static water level measured below level of concrete platform
47N73W16CCA	170	48.0	4,810	5-10-73	1,300	10.0	
47N73W18BBC	189	120.6	4,915	5-30-73			Depth measurement uncertain
47N73W19BAD	205	177.9	4,885	5-10-73	1,000	9.5	
47N73W22DDB	261	146.8	4,880	5-13-73	1,125	11.5	
47N73W25DBD	272	154.2	4,890	5-13-73	1,475	10.5	
47N73W27CBB	200	166.0	4,930	5-10-73			
47N73W30CAD	145	41.4	4,935	5-10-73	390	11.0	
47N73W32DAB	180	128.5	4,960	5-10-73	1,235	12.0	
48N69W1BCD	31	9.5	4,237	6-21-73	580	10.0	
48N69W7DAC	128	74.4	4,445	6-21-73	1,525	12.0	
48N69W10BAB	232	76.7	4,345	6- 5-73	330	11.5	
48N69W15BBA	80	5.3	4,290	6- 5-73	1,000	11.5	
48N69W17AAD	99	64.1	4,355	6-20-73	1,775	11.0	Water level measured from bottom of metal flange on top of concrete slab around casing
48N69W20BCB	130	95	4,380	6-20-73	1,825	11.0	Measurement accuracy ± 1 foot. Initial wetted-tape measurement indicated water level of 95 feet below surface. Check measurement would not pass obstruction at 91 feet below surface
48N69W26CBA	101	29.1	4,305	6- 5-73	1,825	11.0	
48N69W29ADD	86	32.8	4,318	6- 1-73	950	10.5	
48N69W29DDD	36	31.6	4,320	6- 1-73			Could not sample, water on tape had bad odor
48N69W31BCC	123	65.9	4,396	6- 1-73	1,875	13.0	

Table 10.--Table of selected wells in Gillette area, Wyoming--continued

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement	Conductivity	Temperature °C	Remarks
48N69W35BCB	141	13.3	4,310	6- 5-73	2,000	11.0	
48N69W35CDC	158	59.3	4,364	6- 5-73	2,000	12.0	
48N71W2ADA	67	22.1	4,652	6- 6-73	4,700	11.5	
48N71W3BDD	193	57.2	4,608	6-27-73	4,100	9.5	
48N71W5DBA	77	45.3	4,615	5-16-73	3,100	11.5	
48N71W6CBC	150	92.2	4,575	5-15-73	2,800	11.5	
48N71W9BDD	200	116.6	4,612	6- 6-73	735	11.0	Depth measurement uncertain
48N71W12BCD	357	155.9	4,635	6- 6-73	1,775	13.0	
48N71W21ACC	108	92.6	4,580	5-16-73	1,525	13.5	
48N71W23AAA	87	41.8	4,525	6- 1-73	1,300	14.0	
48N71W29CCB	69	23.6	4,505	5-14-73	2,050	10.5	
48N71W30BBB	130	44.6	4,570	5-15-73	4,400	11.5	
48N71W33BAA	90+	57.5	4,520	5-14-73	975	14.0	Depth to top of pump, weight would not pass pump
48N72W1DAC	206	96.3	4,578	5-15-73	3,200	11.5	
48N72W7ABC	127+	62.4	4,661	5-12-73	3,200	11.0	Depth to top of pump, weight would not pass pump
48N72W13ADB	122	59.4	4,615	5-15-73	2,050	11.5	
48N72W14ABB	52	34.7	4,598	5-15-73	3,100	11.0	
48N72W17ACA	73	3.2	4,600	5-12-73	4,600	9.0	
48N72W21ACB	73	27.6	4,595	5-15-73	3,900	10.0	
48N72W32CBC	59	13.4	4,615	5-13-73	2,900	11.0	
48N72W34DDB	77	20.0	4,558	5-13-73	3,200		Conductivity measured from water in tank
48N73W1ABD	143	101.8	4,710	5-11-73	2,600	9.5	
48N73W5CD	187	107.0	4,828	5- 9-73	2,300	10.0	

Table 10.--Table of selected wells in Gillette area, Wyoming--continued

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement	Conductivity	Temperature °C	Remarks
48N73W7CDB	202	20.3	4,832	5- 9-73	1,350	9.5	
48N73W9BBC	148	25.3	4,838	4-18-73	2,800	8.0	
48N73W10CBD	242	155	4,815	5-11-73	1,600	11.5	Shut pump off on arrival. Water level rising about 0.4 feet/minute after 15 minutes
48N73W16BCB	355	215.4	4,781	5- 9-73	500	12.0	Reported depth
48N73W16DAA	291	138.6	4,750	5- 9-73	700		
48N73W17AAB	201	18.6	4,790	5-30-73	2,125	9.5	
48N73W20ACB	180	87.4	4,850	5- 9-73	1,300	11.0	
48N73W23BBA	69	10.2	4,700	5-30-73	650	10.5	
48N73W24BBB	83	39.8	4,695	5-11-73	580	9.5	
48N73W25BCC	195	91.1	4,665	5-10-73	520	12.0	
48N73W29BBC	90	62.9	4,845	5-10-73			
48N73W33CBA	171	78.8	4,790	5-30-73	1,775	11.0	Original well depth reported to be 285 feet
48N74W12DBC	141	109	4,890	4-18-73	2,350	9.0	Shut pump off on arrival. Water level rising slowly after 30 minutes
49N69W1ACA	223	160.5	4,410	6-22-73	2,175	13.5	
49N69W2BA	144	119.7	4,350	6-22-73	1,775		Reported depth
49N69W5ABA	81	28.4	4,290	6-22-73	500	12.0	
49N69W6CBC	94	11.5	4,355	6-22-73	5,500		
49N69W8BCA	100	43.4	4,325	6-22-73	2,900	12.0	Depth uncertain
49N69W9ACD	83	25.8	4,305	6-22-73	2,600	12.0	Original well depth reported to have been 400 feet, apparently caved
49N69W10BBC	146	75.6	4,332	6-22-73	1,775	10.0	
49N69W10BDD	54	34.2	4,325	6-22-73	1,875	11.5	

Table 10.--Table of selected wells in Gillette area, Wyoming--continued

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement	Conductivity	Temperature °C	Remarks
49N69W11AAA	232	153.6	4,410	6-21-73	2,350	11.5	
49N69W13BDD	227	65.9	4,460	6-21-73	1,950	12.0	Original well depth reported to be 255 feet
49N69W14BCA	107+	56.7	4,365	6-21-73	2,000	11.0	Depth to top of pump, weight would not pass pump
49N69W19AAD	173	70.2	4,355	6-20-73	2,900	13.5	
49N69W21DAA	160	96.2	4,375	6-21-73	3,100	13.5	
49N69W24CCD	185	87.1	4,364	6-21-73	2,350	10.5	Reported depth
49N69W25DDC	204	23.6	4,290	6-21-73	2,350	10.5	
49N69W27CDC	91	40.9	4,318	6-20-73	3,500	11.5	
49N69W29AAC	144	76.6	4,375	6-20-73	5,100	13.5	Depth uncertain. Original well depth reported to be 175 feet
49N69W29CBD	80	38.0	4,363	6-20-73	2,475	11.5	Reported depth
49N69W31CBC	520	246.5	4,525	6-20-73	560	13.5	Reported depth
49N69W34CCD	199	48.2	4,307	6-21-73			
49N69W34DAA	119	53.8	4,315	6- 5-73	2,600	11.5	
49N70W2BAA	140	100.9	4,390	6-22-73	2,600	12.0	
49N70W7ADC	105	52.8	4,480	6-19-73	765	10.0	
49N70W12ACB	126	96.4	4,410	6-22-73	375	14.0	
49N70W25ACA	105	35.2	4,390	6-20-73	1,175	11.5	
49N70W25CBB	33	14.3	4,424	6-20-73	460	11.0	
49N70W32BDA			4,750				
49N71W1ADD	79	66.5	4,577	6-26-73	2,125	13.0	
49N71W7BBD	56	34.3	4,565	5-17-73	1,400	13.0	
49N71W8AAA	258	116	4,504	5-17-73	1,600	13.5	Shut pump off on arrival. Water level still rising after 30 minutes
49N71W8CD	119	38.8	4,583	5-16-73	2,700	11.0	
49N71W10ABA	192	26.0	4,500	5-16-73	2,225	13.0	

Table 10.--Table of selected wells in Gillette area, Wyoming--continued

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement	Conductivity	Temperature °C	Remarks
49N71W12CAD	152	44.9	4,570	5-17-73	1,950		
49N71W16ABC	204	116.4	4,584	5-16-73	1,775	14.5	
49N71W18DCC	87	42.4	4,638	5-16-73	240	10.5	
49N71W20DDA	121	55.5	4,695	5-16-73	480	11.5	
49N71W23BDC	84+	49.0	4,600	5-17-73	2,700	10.5	Depth to top of pump, weight would not pass pump
49N71W25DCC1	128	54.9	4,640	6- 6-73		14.0	
49N71W25DCC2	45	20.4	4,650	6-19-73	765	10.5	
49N71W26DCD	690	375.5	4,735	6- 6-73			
49N71W27DCD	149	117.2	4,758	5-16-73	3,200	13.0	
49N71W30DCA	158	110.4	4,685	5-15-73			
49N72W4AAC	120	68.2	4,565	6- 7-73	2,600	12.0	
49N72W6ADB	120	47.4	4,590	5-13-73	1,875	9.5	
49N72W7DBB	206	142.9	4,690	5-12-73			
49N72W8BCC	120+	84.7	4,625	5-30-73			Depth to top of pump, weight would not pass pump
49N72W10CBA	335	126.8	4,625	5-12-73	1,775	10.0	
49N72W14BAB	183	63.4	4,601	5-17-73	3,600	11.5	
49N72W16ABB	219	121.4	4,618	6- 7-73	1,775	11.0	
49N72W16ABB	69	36.2	4,618	6- 7-73			Could not sample, water on tape had bad odor
49N72W18DAA	222	19.7	4,700	5-11-73	1,650	10.5	
49N72W19CCC	461	131.1	4,855	5-11-73	2,235	10.5	
49N72W21AAC	144	116.6	4,695	5-12-73	3,600	11.5	
49N72W23CCA	88	74.3	4,678	5-17-73	2,175	12.0	
49N72W25BDA	166	85.4	4,716	5-16-73	520	13.0	

Table 10.--Table of selected wells in Gillette area, Wyoming--continued

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement	Conductivity	Temperature °C	Remarks
49N72W26DBA	188	155.2	4,750	5-16-73	2,600	13.0	
49N72W30DDC	238	157.5	4,790	5-11-73	1,050	10.0	
49N72W33CAD	148	81.3	4,785	5-15-73	3,600	13.5	
49N72W34DCD	189	153.4	4,760	5-15-73	3,750	11.5	
49N73W1BCA	99	50.4	4,660	5-12-73	875	11.0	
49N73W2BDD	82	21.5	4,675	5-30-73	2,475	10.0	
49N73W7DAA	171	53.5	4,760	4-17-73	580	10.5	
49N73W9BBA	90	48.5	4,805	5-30-73	4,100	11.5	
49N73W9BBD	339	215.5	4,820	4-17-73	2,175	11.0	
49N73W9CDC1	117	87.5	4,795	4-18-73			
49N73W9CDC2	467	284.4	4,795	4-18-73	1,775	12.0	
49N73W12CCB	156	47.8	4,740	5-12-73	3,100	10.0	
49N73W13BBD	115	66.5	4,840	5-12-73	3,100	11.0	
49N73W15DDC	176	116.9	4,798	5-30-73	2,600	12.5	
49N73W19ABB	218	162.6	4,745	4-17-73	1,700	10.5	
49N73W20DAB	425	63.4	4,855	4-18-73			
49N73W23CBB	166	106.2	4,880	6- 7-73	270	13.0	
49N73W26BDA	265	123.2	4,825	5- 9-73	2,225		Depth measurement uncertain
49N73W28CBC	233	63.5	4,785	4-18-73	2,700	10.0	
49N73W31BBD	246	96.8	4,815	4-18-73	2,225	10.0	
49N73W35CDA	112	48.0	4,720	5-11-73	1,000	10.5	
50N69W1DDD	144	21.6	4,320	7-14-73	1,700	11.0	
50N69W2ACC	160+	128.8	4,395	7-14-73			Depth to top of pump, weight would not pass pump
50N69W3BCB	174	99.5	4,322	6-23-73	560	13.5	
50N69W5DCC	114	112.9	4,340	7-12-73			Well probably caved at about water level

Table 10.--Table of selected wells in Gillette area, Wyoming--continued

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement	Conductivity	Temperature °C	Remarks
50N69W6DAA	314	142.4	4,362	7-13-73	1,000	11.5	Water enters casing at depth of about 62 feet and runs down inside casing
50N69W11BBB	163	82.7	4,315	6-23-73	950	9.5	
50N69W14ABD	103	32.9	4,290	6-23-73	1,525	12.0	
50N69W14CCD	14	4.2	4,235	7-15-73	1,950	14.5	
50N69W14DCB	49	17.6	4,250	7-15-73	1,600	11.5	Original well depth reported to have been 80 feet
50N69W18CCB	57	27.0	4,335	7-12-73	2,000	11.5	
50N69W19BAB	36	10.1	4,310	6-23-73			Could not sample, water on tape had bad odor
50N69W22BCD	106	49.6	4,310	7-15-73	3,100	13.0	
50N69W23ACC	245	9.2	4,240	7-15-73	2,475	12.5	Reported depth
50N69W25BBA	40	10.6	4,225	7-15-73	3,500	11.5	Original well depth reported to have been 50 feet
50N69W26ACB	139	69.4	4,300	7-15-73	3,300	11.5	
50N69W27AAA	242	81.3	4,310	7-15-73	3,300	14.0	
50N69W27BCC	152	15.0	4,255	6-23-73	2,050	11.5	
50N69W30CBC	32	13.5	4,289	6-23-73	1,775	10.0	
50N69W33DAA	118	63.4	4,295	6-22-73	1,950	10.0	
50N70W1AAB	159+	149.7	4,320	6-23-73			Depth to top of pump, weight would not pass pump
50N70W14ACB	201	186.7	4,438	6-23-73	720	13.0	
50N70W19CDC	185	98.6	4,385	6-28-73	1,475	11.0	
50N70W20DBC	72	12.6	4,355	6-28-73	1,100	13.0	Depth measurement uncertain
50N70W21BAB	236	179.9	4,455	6-28-73	980	13.5	
50N70W21CAD	126	39.6	4,352	6-28-73	2,475	13.0	

Table 10.--Table of selected wells in Gillette area, Wyoming--continued

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement	Conductivity	Temperature °C	Remarks
50N71W2CCB	235	46.8	4,474	6-26-73	1,700	12.0	
50N71W2CCD	138	19.8	4,455	6-26-73	730	11.0	
50N71W2DCA	388			6-27-73	520		Well drilled with mud rotary one week before inventory. Water level and conductivity are questionable
50N71W3AAA	600	315.2	4,448	6-26-73	1,525	13.0	Reported depth. Shut pump off on arrival. After one hour water level still rising. Owner reports water level about 100 feet below surface
50N71W5BCC	71	41.8	4,490	6- 3-73	2,125	11.0	
50N71W6DDC	211	124.5	4,430	6- 4-73	2,600	11.5	
50N71W9BDC		167.0	4,500	6- 4-73	1,775	13.0	
50N71W12CDC	237	144.8	4,510	6-27-73	1,300	14.0	
50N71W14DAD	55	47.5	4,515	6-27-73	4,600	10.5	
50N71W17DBB	215	117.5	4,568	6- 4-73	1,775	11.0	Depth measurement uncertain. Shut pump off on arrival. After 30 minutes water level still rising
50N71W18BAC	129	78.4	4,520	6- 7-73	1,875	14.0	
50N71W19CCC	104	32.6	4,495	6- 4-73	765	11.0	
50N71W19DDD	71	63.1	4,510	6- 4-73	1,475	11.5	
50N71W21CDD	102	34.7	4,425	6- 4-73	2,350	10.0	
50N71W24DAC	150	97.0	4,465	6-27-73	1,525		
50N71W26CAB	252	71.2	4,415	6-26-73	1,200	13.0	
50N71W30DDA	121	99.3	4,525	6- 4-73	2,900	11.5	
50N71W31ACD	33	25.0	4,480	6- 4-73			
50N71W32DBD	62	12.2	4,445	5-17-73	2,900	12.0	
50N71W33BBA	54	28.6	4,430	5-17-73	3,200	13.0	Depth measurement uncertain. Shut pump off on arrival. After 30 minutes water level still rising

Table 10.--Table of selected wells in Gillette area, Wyoming--continued

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement	Conductivity	Temperature °C	Remarks
50N71W34BBC	113	28.1	4,433	6- 4-73	1,875	10.0	
50N71W34BDC	106	62.0	4,485	5-17-73	2,600	12.0	
50N71W35CAD	62	32.4	4,470	6-27-73	3,500	13.5	
50N72W1CBB	88	10.8	4,369	6- 3-73	1,600	9.5	
50N72W4CCC	22	11.4	4,370	4- 5-73	3,300	9.0	
50N72W10DDC	188	66.1	4,415	6- 3-73	1,300	11.5	
50N72W11AAC	309	50.5	4,428	6- 3-73	1,900	10.0	Reported depth
50N72W19CCD	272	177.7	4,658	5-30-73	1,950	10.0	
50N72W23BDC	78	41.0	4,540	6- 7-73	3,750		
50N72W30BBA	21	8.0	4,652	5-30-73	1,125	8.0	
50N72W33AAA	55	36.7	4,560	6- 7-73	4,500	13.0	Original well depth reported to have been about 70 feet
50N72W36DBD	155	34.6	4,490	5-17-73	2,350	11.5	
50N73W5CDC	316	89.9	4,605	4- 8-73			
50N73W8CDC	281	91.9	4,675	4-17-73	3,500	11.5	
50N73W11AB	144	105.9	4,505	4- 7-73	3,600		
50N73W12ACA	303	271.8	4,675	4- 7-73	2,000		
50N73W21CAC	182	40.8	4,730	4-17-73	4,400	11.5	
50N73W23ACB	125	95.1	4,748	4- 7-73	1,525		
50N73W27ADA	283	129.2	4,815	4- 8-73	2,350	10.0	
50N73W30DBA	170	103.0	4,650	4-17-73	3,500	11.5	
50N73W32AAA	71	21.5	4,725	4-17-73	850	11.0	
50N73W32CAD	162	50.4	4,710	4-17-73	2,000	11.0	

Table 10.--Table of selected wells in Gillette area, Wyoming--continued

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement	Conductivity	Temperature °C	Remarks
50N74W24AAA	224	211.9	4,715	4-17-73			Well reported to be 265 feet deep
51N69W3ABC	59	34.5	4,145	7-14-73	1,175	13.0	
51N69W5BCD	152	23.9	4,025	7-11-73	2,000	10.5	
51N69W8BBA	104	48.4	4,050	7-11-73	2,000	11.5	
51N69W9DDA	216	128.3	4,260	7-13-73	1,875	12.0	Original well depth reported to have been 250 feet
51N69W19DCB	173	64.9	4,139	7-13-73	3,200	13.5	
51N69W23BBD	439	201.2	4,460	7-15-73	550	11.5	
51N69W25BDB	86	71.7	4,395	7-14-73			
51N69W27CBA	500	<165	4,302	7-12-73	1,700	12.0	Reported depth
51N69W30CCD	90	58.3	4,205	7-13-73	360	11.5	
51N69W32BCA	219	83.0	4,280	7-12-73	2,300		
51N69W32DDB	73	41.7	4,260	7-12-73	1,050	12.0	
51N69W36ADB	245	160.9	4,430	7-14-73	1,825	12.0	
51N70W1ADD	123	89.3	4,075	7-11-73	1,825	11.5	
51N70W4BBB	259	137.7	4,220	6-28-73	1,775	13.5	
51N70W9BDA	402	178.4	4,261	6-28-73	1,350	13.5	
51N70W10ABC		132.0	4,155	6-28-73	2,000	12.0	
51N70W11CDC	132	52.3	4,070	7-11-73	2,600	13.5	
51N70W15DDB	143	41.8	4,125	7-12-73	4,000	10.0	
51N70W17AAB	145	88.5	4,190	6-28-73	2,125	15.5	
51N70W20CBD	103	30.8	4,280	7-15-73	1,650	14.0	Original depth reported to be 140 feet
51N70W20CCA	28	15.0	4,275	7-12-73	1,650	12.0	
51N70W22CAB	346	182.3	4,243	7-12-73	1,950	13.0	
51N70W23ADC	130	58.8	4,110	7-12-73	3,500	11.0	
51N70W26ADD	79	72.4	4,168	7-13-73			Depth to top of pump, weight would not pass pump

Table 10.--Table of selected wells in Gillette area, Wyoming--continued

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement	Conductivity	Temperature °C	Remarks
51N70W30DCA	294	247.4	4,413	6-27-73	1,475	11.0	
51N70W34CAC	236	205.1	4,370	7-15-73	1,775	13.5	
51N70W35CDA	108	79.6	4,245	6-23-73	3,400	14.0	
51N71W5CAD	322	240.8	4,408	6-25-73	1,200	14.0	
51N71W6CBA	208	51.6	4,168	5-25-73	1,050	13.0	
51N71W25BCB	337	234.9	4,513	6-24-73	390	13.0	
51N71W28BAA	41	16.5	4,315	6- 4-73	700	10.0	
51N71W33BBD	71	56.0	4,345	6- 3-73	1,175	11.0	
51N71W34BAB	43	16.5	4,390	6- 3-73	750	10.0	
51N72W4CDC	150	80.8	4,215	4- 6-73	1,700	8.0	
51N72W7AAC1					2,350		
51N72W11ACC2	64	Dry	4,295	6-25-73			
51N72W11ACC3	171	81.0	4,295	6-25-73			
51N72W11ACC	214	213	4,295	6-25-73			
51N72W11DDA	78	70.1	4,275	6-25-73	3,600		
51N72W13DDA	61	15.0	4,232	6-24-73	925	10.0	
51N72W17CDB	127	92	4,350		1,350		Reported depth and water level
51N72W22DCC	150	24.6	4,270	6-24-73	1,875	13.0	
51N72W35AAD	101	37.2	4,360	6- 3-73	1,175	11.0	
51N73W3DBD	154	57.6	4,315	4- 6-73	2,900	9.0	
51N73W4DBB	165	102.8	4,365	4- 5-73	3,200	12.5	
51N73W6BCC	280+	218.3	4,490	4- 5-73	1,825	12.5	Depth measurement uncertain
51N73W13ACA	77	60.4	4,295	4- 7-73	3,400	9.5	
51N73W20ACC	119	24.6	4,375	4- 5-73	2,900	11.5	Depth measurement uncertain
51N73W23BCD	87	45.5	4,342	4- 7-73	3,750	10.0	

Table 10.--Table of selected wells in Gillette area, Wyoming--continued

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement	Conductivity	Temperature °C	Remarks
51N73W29BCC	64	10.4	4,430	4- 5-73			
51N73W34DBD	230	63.5	4,421	4- 7-73	1,950	10.0	
52N68W31BDC	372	231.2	4,495	7-14-73	2,350	13.0	
52N69W28AB	109+	101.1	4,125	7-13-73			Depth to top of pump, weight would not pass pump
52N70W21CDC		57.9	4,124	7-11-73			
52N70W26ACC	177	48.3	3,985	7-13-73	830	12.0	
52N70W34BCB	138	134.9	4,177	7-11-73			Depth measurement uncertain
52N70W35DCB	145	77.2	4,073	7-11-73	390		Original well depth reported to have been 236 feet
52N71W14BCC	84	58.9	4,035	6-25-73			Original well depth reported to have been 360 feet
52N71W24CDD	398	103.5	4,150	6-25-73			
52N72W6CBD	268	131.8	4,210	4- 4-73	680	13.5	
52N72W7DAC	59	21.8	4,200	4- 6-73	3,300	10.0	
52N72W14ABC	98	8.9	4,004	6-24-73	2,125	11.0	
52N72W24BAA	49	12.1	4,055	6-24-73	1,050	11.5	
52N73W8AAC	225	70	4,160	4- 3-73	2,175	12.0	Reported depth and water level
52N73W10BBA	194	71.4	4,150	4- 5-73			
52N73W15AAC	120	20	4,170		4,600	5.5	Reported depth and water level
52N73W18CAB	447	41.8	4,225	4- 5-73	3,400	12.0	
52N73W21CCA	91	46.7	4,261	4- 5-73	3,750	11.0	
52N73W23CDA	194	114.8	4,320	4- 6-73			
52N73W24DDD	116	25.1	4,255	4- 6-73	790	11.0	
52N73W27CAD	122+	117.4	4,354	4- 5-73	3,750	12.5	Depth to top of pump, weight would not pass pump
53N72W10DDB	110	78.5	3,954	4- 4-73	2,350	11.0	
53N72W33ACB	147	88.7	4,201	4- 4-73	4,000	11.0	

Table 10.--Table of selected wells in Gillette area, Wyoming--continued

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement	Conductivity	Temperature °C	Remarks
53N73W4DCB	340	144.8	4,205	4- 3-73			Reported depth; water-level measurement uncertain
53N73W5BCC	287	212.8	4,205	4- 4-73	1,875	14.5	
53N73W7DAD	63	31.5	4,150	4- 4-73	1,050	11.0	
53N73W24DBA	68	44.9	4,113	4- 4-73	525	11.0	Depth measurement uncertain
53N73W26CBA	113	56.6	4,035	4- 4-73	1,700	11.0	
53N73W30CCC	247	44.2	4,150	4- 5-73			
53N73W34BCB	122	31.1	4,040	4- 5-73	2,225	11.0	
53N73W36CCB	62	19.5	4,075	4- 4-73			

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana

Location number: See text for explanation of well-numbering system.
Depth of well: Well depth, to nearest foot; SP indicates spring at that location.
Depth to water: Depth to water below or above (+) land surface, to nearest 0.1 foot; F, indicates flowing well, no head measurement possible; R, reported; E, estimated.
Altitude of land surface: Altitude of land surface from U.S. Geological Survey 7½-minute quadrangle topographic maps.
Date of measurement: Day, month, and year of measurement.
Conductivity: Field electrical conductance of water, in micromhos per centimeter at 25°C; L, indicates laboratory conductance.
Use of water: U, unused; S, stock; H, household; I, irrigation; P, public supply.
Remarks: Q, indicates chemical analysis available.

Priority area number 1 -- Decker East

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water	Remarks
8S40E22BBC	275	118.3	3,620	10-18-73	520	13.5	U	
8S40E28ABD	107	81.0	3,543	10-11-73	800	12.0	S	
8S40E31ABD	145	96.2	3,615	10-11-73	1,500	10.5	S	
8S40E33ACD		54.8	3,485	10-11-73	1,610L	10.5	S	Q
8S40E33BCD	88	28.0	3,515	10-13-73	1,300	10.0	S	
8S40E34BDA1	53	32.6	3,460	10-11-73	927L	12.Q	I	Q
8S40E34BDA2	40	30.2	3,460	10-11-73	850	12.0	U	
8S40E34BDB	98	13.4	3,454	10-11-73	780	11.0	H	
8S41E21CAB	99	81.7	3,733	10-17-73	650	15.0	S	Q
8S41E24DCB	42	15.6	3,970	10-14-73	3,800	14.0	S	

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority area number 1 -- Decker East

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water		Remarks
8S41E25CCA	420	388.1	4,150	10-14-73	4,900L	13.5	H,S	Q	
8S41E32BBB	196	93.1	3,635	10-17-73	5,500	14.0	S		
8S41E34BCC	181	85.4	3,670	10-14-73	2,500	12.5	S		
9S40E1CCA	125	26.4	3,445	10-18-73	1,900	11.5	S		
9S40E4CDA		95.0	3,542	10-13-73			S		
9S40E5BAC	238	68.2	3,585	10-13-73	2,000	12.5	S		
9S40E11ADA	32	17.5	3,430	10-17-73	1,750	10.0	S		
9S40E13CAA	108	63.4	3,500	10-18-73	2,400	10.0	S		
9S40E13DCC	75	31.2	3,520	10-17-73	925	11.0	S		
9S40E17ACA	115	110.9	3,545	10-12-73	1,700	9.5	S		
9S40E21CDA	276	123.4	3,555	10-12-73	2,700	10.5	H		
9S40E21CDB	188	142.7	3,472	10-12-73	1,590L	14.0	H	Q	
9S40E21DDB	70	29.7	3,505	10-13-73	4,500	10.0	S		
9S40E22DAA	169	40.7	3,455	10-18-73	2,840L	10.0	S	Q	
9S40E29CCA	151	39.0	3,520	10-16-73	1,750L	11.0	H	Q	
9S40E30BBA	125	109.4	3,562	10-16-73	5,500	10.0	S		
9S40E36ADA	290	190.0	3,725	10-18-73	2,800	14.0	S		
9S41E1DAD	180	107.0	3,800	10-14-73	2,300	11.0	S		
9S41E6DDC	73	41.5	3,498	10-15-73	4,500	10.0	S		
9S41E7CCB	102	79.2	3,513	10-17-73	1,800	14.0	U		
9S41E8CDB	105	42.8	3,550	10-15-73	850	10.0	S		
9S41E9ACB	29	4.9	3,515	10-14-73	2,620L	10.5	S	Q	
9S41E12BDC	SP		3,685	2-27-74	2,550L	1.5	S	Q	
9S41E15ABD	26	4.7	3,550	10-18-73	1,400	10.0	S		
9S41E17CBC	96	26.3	3,570	10-15-73	2,800	10.0	S		
9S41E26AAD	40	9.3	3,688	10-15-73	4,000	9.5	S		

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority areas number 2 and 3 -- Lower Otter Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water	Remarks
3S44E13AAC1	700	F	2,040	12-17-73			U	
3S44E13AAC2	49	15.9	2,040	12-17-73			U	
3S44E13DBB	930	F	2,059	12-19-73	2,250L	13.5	S	Q
3S44E13DDD	300	F	2,056	12-19-73	1,600	12.5	S	
3S45E5DBB1	SP		3,182	1-15-74			S	
3S45E5DBB2	45	24.7	3,182	1-15-74			S	
3S45E6AAA	SP		3,140	1-15-74			S	
3S45E9CCC	280	133.8	3,290	12-17-73			S	
3S45E10BAC	130	119.4	3,210	12-18-73			S	
3S45E13DCB	172	119.3	3,200	1-14-74	3,460L	10.5	S	Q
3S45E14BCC	86	40.6	3,113	12-17-73	2,450	12.0	S	
3S45E14CCA	193	143	3,203	1-14-74			H	
3S45E15DBB	85	26.6	3,094	12-17-73			U	
3S45E15DDD	280	131.8	3,180	12-17-73	2,010L	10.0	S	Q
3S45E16DDD	75	34.6	3,100	12-18-73	2,400	8.5	S	
3S45E18BBB	900	40	3,020	12-18-73			S	Formerly a flowing well
3S45E19DCC	1,000	F	2,988	12-18-73	2,800	14.0	S	
3S45E19DDB1	100	9.2	2,963	12-18-73			S	
3S45E19DDB2	280	9E	2,963	12-18-73	1,600	7.5	H	
3S45E19DDB3	100	F	2,963	12-18-73	1,380L	7.5	S	Q
3S45E21ABC	75	40.0	3,050	12- -73			S	
3S45E21ABD	280	38.0	3,040	12-17-73	1,600	8.5	H	
3S45E22BAA	250		3,117	1-12-74	2,050L	14.0	H	Q
3S45E22BBB1	80	50R	3,076	12-20-73	1,550L	8.5	H	Q
3S45E22BBB2	77	47.6	3,078	12-20-73			U	

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority areas number 2 and 3 -- Lower Otter Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water		Remarks
3S45E23DAD	150	60R	3,100	12-21-73	1,160L	11.0	S	Q	
3S45E23DCB	81	53.6	3,104	12-21-73			U		
3S45E26BAB	200		3,085	12-20-73	1,300	11.5	S		
3S45E27AAA	78	50.5	3,080	12-20-73			U		
3S45E27ABC	60	40.7	3,062	12-20-73			U		
3S45E27ACB1	195		3,061	12-20-73	1,300	10.0	H		
3S45E27ACB2	55	39.1	3,058	12-20-73	3,800	10.0	S		
3S45E27ACB3	65	39.5	3,060	12-20-73			S		
3S45E32DDA	50	14.8	3,010	12-21-73			H		
3S45E32DDB	60		3,024	12-21-73	3,000	10.0	S		
3S45E33BCB	900	F	3,000	12-18-73	1,380L	12.5	S	Q	
3S45E33BCD	900	F	3,022	12-18-73			S		
3S45E33CBD	435	F	3,020	12-21-73	1,470L	12.5	S	Q	
3S45E36ACB	SP		3,260	1-12-74			S		
3S46E6AAD	292	25.6	3,280	12-21-74	1,570	10.0	S		
3S46E7ADB	133	44.9	3,269	1-18-74	4,210L	8.0	S	Q	
3S46E12ADD	SP		3,554	12-29-73	1,720L	9.0	S	Q	
3S46E14CBC	55	17.1	3,308	1-17-74	1,940L	8.0	H	Q	
3S46E15CAA	130		3,287	1-17-74	2,260L	9.0	S,H	Q	
3S46E15DBC	70	11.5	3,284	1-17-74			S		
3S46E16ADC	152	49.9	3,290	1-11-74			S		
3S46E17ADB	63	51.3	3,240	1-17-74			U		
3S46E17DBD	85	55R	3,208	1-17-74	2,720L	7.5	H,S	Q	
3S46E18BDA	SP		3,208	1-18-74	4,510L	6.0	S	Q	
3S46E18CCD	80	26.4	3,160	1-14-74			S,I		

Table 11.--Table of selected wells and springs, Birney-Decker are Montana--continued

Priority areas number 2 and 3 -- Lower Otter Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water	Remarks
3S46E19ACB	205	47.4	3,210	1-11-74			S	
3S46E19BBA	80	27.7	3,155	1-14-74	4,940L	8.5	S	Q
3S46E20DBA	140	97.0	3,305	1-17-74			S	
3S46E21CAC	240	132.1	3,347	1-13-74			S	
3S46E22CBB	193	99.0	3,350	1-17-74			S	
3S46E23AAA	45		3,344	1-11-74			S	
3S46E30BCD	170	94.5	3,253	1-13-74			S	
3S46E31AAD	SP		3,372	1-16-74			S	
4S44E24ABB	SP		3,545	1-14-74	5,040L	3.0	S	Q
4S45E2CDD	80	55.7	3,080	12-21-73			S	
4S45E3DDD	88	41.7	3,060	12-20-73			U	
4S45E4BDC	430		3,024	12-21-73		12.5	H	
4S45E4DBC	250	F	3,015	1-12-74	1,050L	13.0	H	Q
4S45E4DBD	50	10.9	3,015	1-12-74	2,590L	10.0	S	Q
4S45E9CAA	1,100	F	3,045	12-19-73	2,150	15.5	S	
4S45E9DDA	360	12.1	3,030	12-20-73	1,150	12.0	S	
4S45E9DDB	800	23+	3,030	12-20-73	2,350	16.0	S	
4S45E10BCC	1,000	F	3,060	12-20-73	2,800	13.5	S	
4S45E12ABB	41	25.1	3,117	1-15-74			S	
4S45E15CCA	700	F	3,041	12-20-73	2,340	11.0	S	
4S45E15CCD	700	6.1+	3,050	12-19-73	1,570L	14.0	S	Q
4S45E19DAC	326	260R	3,290	9- 6-67			S	
4S45E20CCA	185	130R	3,245	12-19-73	2,540L	10.0	H	Q
4S45E22ADC	440	F	3,058	1-29-74	1,520L	15.5	S	Q
4S45E22CBD	700	F	3,080	12-19-73	930	13.0	S	

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority areas number 2 and 3 -- Lower Otter Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water		Remarks
4S45E23CCC	454	F	3,080	12-19-73	1,010	14.5	S	Q	
4S45E26ADA	150	75R	3,160	12-18-73			S		
4S45E27DBC1	360	F	3,078	12-17-73	988L	11.0	S	Q	
4S45E27DBC2	318	F	3,080	12-17-73			S		
4S45E27DBD	59	22.4	3,075	12-17-73			U		
4S45E28DAA	129	60.0	3,160	12-17-73			S		
4S45E30DDB	SP		3,452	1-14-74	1,790L	3.0	S	Q	
4S45E32CAD	SP		3,398	1-14-74	2,600L	5.5	S	Q	
4S46E1DDC	82	40.0	3,479	1-16-74			S		
4S46E4DCD	96	48.2	3,274	1-10-74			S		
4S46E5BCB	196	84.0	3,215	1-12-74			S		
4S46E9BBC	310	189R	3,290	1-12-74			S		
4S46E10BCB	41	24.5	3,282	1-16-74			S		
4S46E11BBB	85	58.5	3,357	1-13-74			S		
4S46E15CCA	250		3,620	9-20-67			S		
4S46E27DCD	SP		3,559	1-16-74			S		
4S46E28DAB	SP		3,480	1-16-74	5,720L	7.5	S	Q	
4S46E29CBB	SP		3,335	1-16-74	5,600L	8.0	S	Q	
4S46E31CCC	240		3,180	1-17-74	2,270L	8	H	Q	
4S46E31DDB	18	10.3	3,212	1-16-74	4,000	8.5	S		
4S46E32DCD	65	35	3,242	1-16-74			S		
4S46E33CBA	60	33.6	3,300	1-16-74			S		
4S46E34ABD	SP		3,570	1-16-74	5,290L	5.5	S	Q	
4S46E36BCD	SP		3,505	1-13-74			S		
5S44E24BAA	SP		3,860	1-12-74			S		

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority areas number 2 and 3 -- Lower Otter Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water	Remarks
5S45E2ACC1	1,250	F	3,145	12-18-74	1,910	8.5	S	
5S45E2ACC2	550	8R	3,122	12-18-74	900	8.0	H	
5S45E3ACB	650		3,118	12-18-74	1,740L	7.0	S	Q
5S45E4BBD	250		3,239	1-13-74	1,010L	13.0	S	Q
5S45E4BDD	SP		3,200	1-14-74			S	
5S45E5AAA	270	180R	3,300	1-12-74			S	
5S45E6DAA	SP		3,320	10- -68	1,570L	4.5	S	Q
5S45E7DDA	SP		3,420	1-12-74	1,650	0.0	S	
5S45E8BDC	SP		3,398	1-13-74	1,820	8.0	S	
5S45E8BDD	SP		3,360	1-13-74	1,790L	8.0	S	Q
5S45E8CDC	SP		3,358	1-12-74	2,900	3.0	S	
5S45E9DDA	970	30	3,205	10- 3-68	2,480	11.0	S	
5S45E11BBA	1,020	F	3,120	12-19-73	2,450	16.5	S	
5S45E14AAA	1,200	F	3,155	12-20-73	2,830L	16.5	S	Q
5S45E15DAA	1,243	F	3,145	12-18-73	2,500L	13.5	S	Q
5S45E16DCB	192	>150	3,340	12-20-73			S	
5S45E18AAC	SP		3,440	1-12-74			S	
5S45E18ADB	SP		3,440	1-12-74	2,880L	1.0	S	Q
5S45E18BDA	SP		3,490	1-12-74			S	
5S45E26BAB	40		3,150	12-17-73	2,750L	10.5	S	Q
5S45E27BDD	252	120.0	3,270	1-12-74			S	
5S45E28BBB	250	163R	3,325	1-12-74			S	
5S45E29ADD	SP		3,450	1-16-74	2,940L	6.0	S	Q
5S45E29BDD	SP		3,442	1-15-74			S	
5S45E34ABD	162	53.5	3,220	1-16-74	4,100	10.5	S	

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority areas number 2 and 3 -- Lower Otter Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water	Remarks
5S46E2DDC		35	3,400	1-16-74			S	
5S46E4DAC	70	45.1	3,302	1-16-74	2,000	10.0	S	
5S46E4DDA	80	41.2	3,310	1-16-74			S	
5S46E5BDC	70	42E	3,250	1-12-74		10.5	S	
5S46E9DAD	SP		3,420	1-16-74	2,180L	4.5	S	Q
5S46E20ABC	SP		3,370	1-18-74	2,850L	3.5	S	Q
5S46E20CBC	60	12.3	3,255	1-15-74			U	
5S46E20CDA1	18	1R	3,260	1-15-74	3,640L	8.0	S	Q
5S46E20CDA2	370	67R	3,260	1-15-74			U	
5S46E21DDA			3,340	1-18-74	2,300L	8.5	S	Q
5S46E23CAC	84	29.1	3,405	1-18-74	520	8.5	U	
5S46E23CBD	61	29.8	3,405	1-18-74			U	
5S46E24BCC1	30		3,450	1-18-74	2,360L	8.5	H	Q
5S46E24BCC2		29.6	3,450	1-18-74			S	
5S46E27BAA	SP		3,395	1-18-74	4,300L	2.0	S	Q
5S46E28BBA	26	2.6	3,282	1-15-74			U	
5S46E29ABA	SP		3,278	1-15-74	2,650L		S	Surface water sampled below field of springs; Q

Priority areas number 4 and 5 -- Upper Otter Creek

8S44E2AAD	48	36.3	3,742	11-16-73	1,830L	9.0	S	Q
8S44E2ADA	13	7.8	3,735	11-16-73			U	
8S44E2BBD	SP		3,760	11-16-73			S	Q
8S44E12ACA	SP		3,745	11-17-73	3,260L	5.0	S	Q
8S44E35ADC	28		4,016	11-15-73	672L	9.5	S	Q; this was the only well available during the 1930's

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority areas number 4 and 5 -- Upper Otter Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water	Remarks
8S45E3BAA	SP		3,680	2-27-74	2,290L	1.0	S	Q
8S45E3DAA	SP		3,700	2-27-74	2,770L	6.0	S	Q
8S45E4ABA	25		3,555	2-27-74	4,480L	12.0	H,S	Q
8S45E4ACC	SP		3,600	2-27-74	3,700L	2.5	S	Q
8S45E4DCC	SP		3,645	2- 2-74			S	
8S45E8DBA	SP		3,790	2- 2-74	1,190L	6.0	S	Q; yield, 7 gpm
8S45E10ABC	30	6.8	3,600	2- 2-74	2,850	6.0	S	
8S45E13BCA	SP		3,860	2- 3-74	949L	4.0	U	Q
8S45E14DBB	SP		3,740	2- 2-74			S	
8S45E14DDA	10	5E	3,818	2- 1-74			U	
8S45E15DBB	SP		3,640	2- 2-74	373L	0.5	S	Q
8S45E16AAC	SP		3,718	2- 2-74			S	
8S45E16ABA	SP		3,700	2- 2-74			S	
8S45E16DDC	42		3,680	2- 2-74	5,840L	8.5	S	Q
8S45E17AAD	SP		3,780	2- 2-74			S	
8S45E19CBC	SP		3,910	11-14-73			S	
8S45E20AAC	35	10.7	3,718	2- 2-74			S	
8S45E21ABB	SP		3,750	1-31-74			S	
8S45E22BAA	19	7.9	3,675	1-31-74	4,200	5.0	S	
8S45E24CAD	SP		3,818	2- 3-74	5,300L	3.5	S	Q
8S45E27BDB1	45		3,718	1-31-74	6,380L	8.5	S	Q
8S45E27BDB2	61	23.1	3,718	1-31-74			U	
8S45E27BDB3	180	32.2	3,718	1-31-74	4,200L	10.5	H	Q
8S45E27CCA	40	7.5	3,735	1-30-74			S	
8S45E28AAC	262	105.4	3,775	1-31-74			U	

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority areas number 4 and 5 -- Upper Otter Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water	Remarks
8S45E30BCD	SP		3,850	11-14-73	5,000	7.0	S	
8S45E31DAB	SP		3,860	2- 1-74			U	
8S45E33AAD	10	F	3,740	1-30-74			S	Flowing alluvial well
8S45E33BAA	50	22R	3,770	1-30-74	5,270L	8.0	H	Q
8S45E33BAD	30		3,770	1-30-74	5,000L	9.5	S	Q
8S45E33BBD	30	6.1	3,778	2- 2-74	3,840L	8.5	S	Q
8S45E34CAA1	130R		3,760	1-30-74			S	
8S45E34CAA2	20	6.8	3,760	1-30-74	4,040L	7.5	S	Q
8S45E36BCC	250		3,900	2- 3-74			S	
8S46E1BAA	60	36.1	3,641	2- 6-74			S	
8S46E1CDA	220	137.1	3,819	2- 6-74			S	Q
8S46E2AAB	SP		3,721	2- 6-74	1,660L	3.0	S	Q
8S46E2ABC	SP		3,790	2- 6-74			S	
8S46E2BDD	SP		3,835	2- 7-74			S	
8S46E2DBC	70	54.4	3,888	2- 6-74			S	
8S46E4DAC	21	8.2	3,709	2- 7-74	4,120L	6.0	U	Q
8S46E4DDD	SP		3,720	2- 7-74	2,590L	2.0	S	Q
8S46E5CBD	55	20R	3,542	2- 7-74			S	
8S46E5DAD	16	10R	3,608	2- 7-74	3,070L	4.0	S,H	Q
8S46E5DDA	SP		3,617	2- 7-74			S	
8S46E13AAD	SP		3,840	2- 6-74			S	
8S46E13BAA	SP		3,890	2- 6-74			S	
8S46E15CDB1	SP		3,720	2- 4-74			S	
8S46E15CDB2	SP		3,718	2- 4-74			S	
8S46E16DAB	14	11.3	3,695	1-31-74			U	

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority areas number 4 and 5 -- Upper Otter Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water		Remarks
8S46E17CDB	30	10.6	3,652	2- 4-74	5,080L	2.5	S	Q	
8S46E17CDD1	SP		3,645	2- 4-74			S		
8S46E17CDD2	SP		3,650	2- 4-74			S		
8S46E19ADD	SP		3,650	1- 30-74			S		
8S46E20ABB	SP		3,664	2- 4-74			S		
8S46E20CCC	33	8.9	3,668	1-30-74	6,070L	5.5	S	Q	
8S46E21BCC	SP		3,710	2- 4-74			S		
8S46E21CBA	SP		3,718	2- 4-74	4,470L	6.5	S	Q	
8S46E22ADB	SP		3,760	2- 4-74			S		
8S46E23ACC	SP		3,820	2- 6-74	1,730L	0.5	S	Q	
8S46E23CCA	SP		3,803	2- 4-74	3,670L	2.5	S	Q	
8S46E23DAB	SP		3,850	2- 4-74			S		
8S46E24CCD	160		3,880	1-31-74	4,020L	8.5	S	Q	
8S46E25CCD	SP		3,900	2- 4-74			S		
8S46E26ABC	SP		3,855	2- 4-74			S		
8S46E26ACB	SP		3,838	2- 4-74			S		
8S46E26ACC1	50	11.3	3,865	2- 4-74	2,200	3.5	S	Q	
8S46E26ACC2	18	3.0	3,857	2- 4-74	1,900L	3.5	U	Q	
8S46E28ACD	75	14.0	3,760	1-31-74			S		
8S46E28ADC	SP		3,765	2- 1-74			S		
8S46E28BAA	SP		3,740	2- 1-74			S		
8S46E28DAA	33	13.2	3,773	1-31-74			S		
8S46E29BBA	SP		3,680	1-30-74			S		
8S46E32ABA	20	5.5	3,727	1-30-74	5,620L		S	Q	
8S46E34BAC	SP		3,800	2- 1-74			U		

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority areas number 4 and 5 -- Upper Otter Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water		Remarks
8S47E6BCA	18	11.8	3,708	2- 6-74			U		
8S47E6BCB	SP		3,690	2- 6-74			S		
8S47E7BAB	SP		3,730	2- 6-74	3,400L	6.0	S	Q	
8S47E7CCB	80	13.8	3,797	2- 6-74			U		
8S47E30DCC	SP		4,070	2- 4-74			S		
9S44E11AAB	SP		3,798	11-18-73		4.0	S	Q	
9S45E3AAD	40	39	3,840	2- 1-74			U		
9S45E3ABC		9.4	3,790	1-30-74			S		
9S45E3ADC	82	18.2	3,822	1-29-74	5,530L	10.0	S	Q	
9S45E4BBA	28	16.8	3,802	1-30-74	6,500	7.0	S		
9S45E6DDB	SP		3,960	2- 2-74			S		
9S45E7CCA	260		3,900	11-19-73	1,990L	12.0	H	Q	
9S45E11BCD1	16		3,844	1-29-74	3,500	8.0	S		
9S45E11BCD2	7	5.8	3,844	1-29-74			U		
9S45E12CBC		125.9	3,930	1-29-74	1,750L	10.5	S	Q	
9S45E14BAC		49.2	3,890	1-29-74			S		
9S45E16AAA	30	6.1	3,905	1-31-74	2,920L	8.0	S	Q	
9S45E18ACC	SP		3,910	2- 2-74	575	0.5	S	Q; probably diluted with runoff	
9S46E1ADD	SP		4,020	2- 2-74			S		
9S46E2ACB	SP		3,900	2- 3-74			S		
9S46E3AAB	50	15R	3,850	1-31-74	5,560L	4.5	H,S	Q	
9S46E3DDD	200	118.4	3,958	2- 5-74			H,S		
9S46E4ACB	160		3,822	1-31-74	2,700	10.5	S	Q	
9S46E4BCA	SP		3,780	1-29-74	8,400L	8.5	S	Q	
9S46E4CCD	SP		3,810	1-29-74			S		

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority areas number 4 and 5 -- Upper Otter Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water	Remarks
9S46E5BCB1	53	26.3	3,818	1-30-74	4,340L	6.0	S	Q
9S46E5BCB2	330	150R	3,808	1-30-74	1,930L	9.0	H	Q
9S46E5DAB	165	56.0	3,810	1-29-74	3,230L	9.0	S	Canyon coal; Q
9S46E5DDA	38	7.2	3,810	1-29-74	4,770L	6.5	S	Q
9S46E6ADA	76	23.5	3,818	1-30-74	4,300L	6.0	S	Dietz or Anderson; Q
9S46E6ADD	300	115.9	3,818	1-30-74	1,920L	6.5	H	Q
9S46E7DDC	135	62.2	3,922	1-30-74			S	Dietz or sandstone above
9S46E9DAC	40	23.0	3,858	2- 5-74			S	
9S46E11BDC	160	66.8	3,955	2- 3-74	2,640L	11.0	S	Anderson; Q
9S46E11CAC1	175	106.5	3,955	1-31-74			S	Anderson
9S46E11CAC2	250	123.0	3,960	1-31-74			U	Anderson
9S46E12ACA	SP		4,080	2- 2-74			S	
9S46E12ADC	SP		4,090	2- 2-74			S	
9S46E12DAB	18	7.7	4,110	2- 2-74	5,730L	4.5	H,S	Q
9S46E13BAB	SP		4,070	1-31-74			S	
9S46E13DCD	SP		4,040	2- 3-74			S	
9S46E14DDA	SP		4,090	2- 3-74			S	
9S46E15CAC	SP		3,897	2- 5-74			S	Q; above Canyon coal
9S46E15CBD	220	60R	3,938	2- 5-74	4,140L	8.0	S	Q
9S46E17ADA	112	75.1	3,896	2- 5-74			S	Dietz or sandstone above
9S46E19ACA	SP		4,118	1-29-74			S	
9S46E20DCB	SP		4,040	1-29-74			S	
9S46E23ABC	SP		4,053	2- 3-74	4,780L	3.0	S	Q
9S46E28BDC	360	247.0	4,157	2- 5-74			S	
9S46E28DDC	SP		3,960	2- 5-74			S	

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority areas number 4 and 5 -- Upper Otter Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water	Remarks
9S46E29ABC1	SP		4,120	1-29-74			S	
9S46E29ABC2	56	52.5	4,160	1-29-74	3,910L	8.0	U	Q
9S46E29ACB	SP		4,180	2- 3-74			S	
9S46E29CCA1	27	15.6	4,168	2- 5-74			S	
9S46E29CCA2	14	10.8	4,165	2- 5-74	2,140L	3.0	S	Q
9S46E29DBB	SP		4,195	2- 3-74			S	
9S46E34DAB	SP		3,832	1-31-74			S	
9S47E6DCC	SP		4,100	2- 3-74			S	
9S47E7DCD	SP		3,920	2- 3-74			S	
9S47E19BDC	175	107.6	3,904	2- 2-74			S	
9S47E19BDD	SP		3,860	2- 2-74			S	
9S47E19CDB	SP		3,850	2- 3-74			S	
9S47E19DBC	SP		3,830	2- 3-74	5,340L	4.5	S	Q
9S47E30BDD	255	128.9	3,895	2- 3-74			U	
9S47E31CBD	SP		3,785	2- 3-74			S	

Priority area number 6 -- Hanging Woman Creek

8S42E9ADB	25	12.6	3,780	11-19-73			U	Above strippable interval
8S42E13ADC	45	20R	3,595	10-31-73			S	Dietz coal
8S42E14ADC	32	16R	3,680	11-18-73			S	
8S42E15CBB	157	39.9	3,830	11-19-73			S	Anderson
8S42E16DDD	SP		3,934	11-19-73			S	

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority area number 6 -- Hanging Woman Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water	Remarks
8S42E21AAA1	410	220R	3,960	11-19-73			S	Anderson coal and overburden
8S42E21AAA2	SP		3,960	11-19-73			H	
8S42E22CAA	166	120E	3,988	11-18-73			S	
8S42E22DBC			3,985	11-15-73			P	
8S42E23BDB	136	75R	3,882	11-18-73			H,S	
8S42E26CBB	159	91.5	3,810	11-15-73	3,710L	11.0	S	Anderson; Q
8S42E28CAA	133	79.7	3,940	11-14-73			S	Anderson
8S42E35BBB	456	Dry	3,960	10-15-73			U	Dry
8S43E5CBA	40	14.7	3,375	10-31-73	3,000	9.5	U	Below Anderson-Dietz
8S43E11CDB	325	142.8	3,787	11-13-73			S	Below Anderson-Dietz
8S43E13ACC	110	78.3	3,930	11-13-73	900	10.0	S	Anderson overburden
8S43E13BDB	SP		3,880	11-13-73			S	
8S43E16CCD	100		3,510	10-26-73			H	Dietz coal
8S43E16CDB	SP		3,600	10-26-73			H	Yield, 1 gpm; Anderson clinker
8S43E20BCC	SP		3,598	11-19-73		7.0	S	Yield, 2 gpm; Anderson clinker
8S43E23DBD	274	18.1	3,607	2-26-74	5,060L	9.0	S	Q
8S43E28CAC	50	17.2	3,495	10-26-73			S	Below Dietz
8S43E29DAC	68	15R	3,521	10-26-73	1,930L	9.0	S	Dietz coal; Q
8S43E30BBC	47	37.1	3,620	11-15-73	1,550L	9.5	S	Dietz coal; Q; measured 15 minutes after pump shut off
8S44E5BDB	147	53.3	3,855	11-16-73	4,600	11.0	S	Anderson overburden
8S44E7ABA	SP		3,830	11-13-73			S	Anderson overburden
8S44E7BAB	32	19.1	3,755	11-13-73	3,000	10.0	S	Dietz overburden
8S44E9DBD	25	0.5	3,839	11-13-73	3,050	9.0	S	Anderson overburden
8S44E9DCA	SP		3,850	11-13-73	2,900	15.0	S	Anderson overburden

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority area number 6 -- Hanging Woman Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water	Remarks
8S44E15BCC	51	10.0	3,905	11-16-73	2,800	11.0	S	Above strippable interval; Q
8S44E18ABA	38	16.4	3,860	11-13-73	1,500	9.0	S	Above strippable interval
8S44E18ABD	255	205R	3,900	11-12-73	2,590	11.0	H	Q; Anderson coal
8S44E18BAC	341	280R	3,865	11-14-73			U	
8S44E18BCD	336	172.7	3,938	11-15-73	1,440	10.0	U	Anderson coal
8S44E18BDC		5.1	3,890	11-15-73			U	
8S44E19CCB	187	74.2	3,700				U	
8S44E22DCD	190		4,105				S	
8S44E27CCC	SP		3,940	11-18-73	3,350	7.5	S	Yield, 0.5 gpm
9S42E3AAD	60	34.1	3,720	11-14-73			S	Anderson coal
9S42E12BCA	40	16.6	3,655	10-14-73			S	Anderson coal
9S42E25DCA	59	16.5	3,702	11-16-73			S	Above strippable interval
9S42E26CDC	32	4.0	3,764				S	Above strippable interval
9S42E27CDC	66	64.7	3,820	11-17-73			U	Above strippable interval
9S42E35DCC	100	30.2	3,787				S	Above strippable interval
9S42E36BCA	36	8.7	3,730	11-16-73			S	Above strippable interval
9S43E4ABC	60R	11.1	3,520	10-30-73			U	Anderson clinker
9S43E7BCA	46	15.5	3,627	10-30-73	2,310L	9.0	S	Anderson overburden; Q
9S43E10AAB	199	10.0	3,530	10-29-73			U	
9S43E10BBA	75	12.3	3,520	3-20-74	5,450L	9.5	S	Dietz interval; Q
9S43E15CDA		5.4	3,555	10-28-73			S	
9S43E15DAB			3,579	10-28-73	2,250L	10.0	S	Anderson; Q
9S43E21AAD	55	4.2	3,575	10-28073	5,000	10.0	S	Anderson overburden
9S43E25BAD	SP		3,680	2-28-74	777L	5.0	S	Q; Above strippable interval
9S43E27AAA	45	32R	3,590				S	Above strippable interval

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority area number 6 -- Hanging Woman Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water	Remarks
9S43E27CDC	240		3,760	10-28-73	1,900L	12.0		Q; above strippable interval
9S43E29DBA		3.5	3,610	10-28-73			S	Q; above strippable interval
9S43E35BBC	215		3,630	10-28-73			S	
9S43E35CAD	235	30R	3,621	10-28-73			S	
9S43E35CDD	305	30R	3,640	10-29-73	4,250	10.0	S	Anderson
9S44E7ADA	70		3,620	10-30-73	4,340L	10.5	S	Q; Anderson overburden
9S44E8BDA	SP		3,635	10-30-73			S	
9S44E10CBA	50	10.6	3,721	10-30-73			S	Above strippable interval
9S44E20DCA	204	25.6	3,650	10-27-73			S	Below Anderson-Dietz
9S44E27ABC	54	20R	3,715	10-29-73	6,800	9.0	S	Anderson
9S44E28CDC1	SP		3,720	10-27-73	2,720L	12.0	S	Q; above strippable interval
9S44E28CDC2	227	23R	3,720	10-27-73	2,450L	11.0	H	Q; Anderson
9S44E30CCA	SP		3,778	2-28-74			U	
9S44E32ACA	SP		3,780	2-28-74			S	
9S44E32BDB	SP		3,790	10-30-73	1,000	10.0	S	
9S44E33BAD	272	15R	3,702	10-27-73			S	Anderson
9S44E33DDC	SP		3,758	10-27-73	1,300	11.0	S	Above strippable interval
10S42E1AAD	100	55.5	3,920	11-15-73	1,830L	10.0	S	Q
10S42E2AAB	302		3,665	10-29-73	1,910L	12.0	H	Q
10S43E2ABD	40	14.5		11-16-73			S	
10S43E5BDB	52	33.1		11-16-73			S	
10S43E6ABA	161	35R	3,800	11-15-73			S,H	

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority area number 7 -- Cook Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water	Remarks
5S41E10ACB	SP		3,622	3- 2-74	1,140L	4.0	S	Q
5S41E13CAD	117	26.8	3,430	2-28-74			S	
5S41E15CBA	SP		3,585	3- 3-74			S	
5S41E16CDD	SP		3,672	3- 3-74	3,000	5.0	S	
5S41E17ADC	SP		3,711	3- 1-74			S	
5S41E18BBC	SP		3,880	3- 1-74	1,570L	11.0	S	Q
5S41E18CBA	SP		4,000	3- 1-74			S	
5S41E20DDD	14	4.4	3,858	3- 4-74			U	
5S41E21ADC	SP		3,830	3- 4-74			S	
5S41E21BBC	SP		3,840	3- 3-74			S	
5S41E21CAA	SP		3,915	3- 4-74	1,150L	5.5	S	Q
5S41E22DCD	SP		3,880	3- 4-74			S	
5S41E23BAA	SP		3,540	3- 3-74	2,400	4.0	S	Q
5S41E23DAB	SP		3,730	3- 3-74	1,700	3.0	S	Yield, 2 gpm
5S41E26ABA	SP		3,746	3- 4-74	510L	5.5	S	Q; yield, 1 gpm
5S41E27ABB	SP		3,876	3- 4-74			S	
5S41E27BAB	SP		3,856	3- 4-74			S	
5S41E28ABC	SP		3,976	3- 4-74	598L	3.5	S	Q; yield, 0.9 gpm
5S41E28DDD	SP		3,910	3- 5-74	925L	7.0	S	Q; yield, 1 gpm
5S41E30CCB	SP		3,760	3- 3-74				
5S41E31AAA	SP		3,720	3- 4-74	4,540L	1.5	S	Q; yield, 1 gpm
5S41E31CBA	80	14.3	3,630	3- 3-74	1,280L	6.5	S	Q
5S41E31CBB	SP		3,622	3- 4-74	1,510L	3.5	S	Q
5S41E31DDD	SP		3,600	3- 3-74	3,340L	5.5	S	Q
5S41E32CDB	SP		3,590	3- 3-74	3,790L	4.5	S	Q

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority area number 7 -- Cook Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water		Remarks
5S41E35CBC	SP		3,960	3- 5-74	444L	7.5	S	Q	
5S41E36CBB	SP		3,910	3- 5-74	544L	7.5	S	Q	
5S42E16DDB	80	31.9	3,358	3- 2-74	1,230L	9.5	S	Q	
5S42E18DCD	80	38.0	3,358	3- 1-74	1,710L	10.0	S	Q	
5S42E19BAB	100	50R	3,417	3- 2-74			S		
5S42E20ADA	443	343R	3,295	3- 2-74			H		
5S42E20ADD	110	31.6	3,295	3- 2-74	2,200L	7.0	H,I,S	Q	
5S42E21ABD	SP		3,240	3- 2-74			S		
5S42E21BCA	70	36R	3,267	3- 2-74			I		
5S42E21DBA	SP		3,270	3- 2-74	258L	1.5	S	Q	
5S42E22BCB	85	28.2	3,238	3- 2-74	1,350	3.0	H,S		
5S42E22DBB	830	+22.9	3,208	3- 1-74	992L	16.5	S	Q	
5S42E28CBB	365	105.4	3,390	3- 3-74			S		
5S42E30CBC	SP		3,840	3- 5-74	1,430L	5.5	S	Q	
5S42E31CCC	SP		3,940	3- 4-74	384	7.0	S	Q	
6S41E1DBC	SP		3,760	3- 4-74			U		
6S41E2ACC	SP		3,540	3- 3-74	1,690L	4.0	S	Q	yield, 0.7 gpm
6S41E3DAB	80	18.2	3,505	3- 3-74	810	7.0	U		
6S41E11AAA	SP		3,500	3- 3-74			S		
6S41E12BBA	SP		3,495	3- 4-74			U		
6S41E12BDA	SP		3,510	3- 4-74			S		
6S42E2CAB	310	112.9	3,312	3- 5-74			S		
6S42E13BAB	250	F	3,140	3- 6-74	1,840L	10.0	S	Q	yield, 1.6 gpm
6S42E13CAA	290	+11.0	3,125	3- 6-74	1,760L	10.5	S	Q	yield, 0.4 gpm
6S42E14DCA	335	+14.6	3,140	3- 6-74	1,810L	9.5	S	Q	yield, 0.17 gpm

Table 11.--Table of selected wells and springs, Birney-Decker area, Montana--continued

Priority area number 7 -- Cook Creek

Location number	Depth of well (feet)	Depth to water (feet)	Altitude of land surface (feet)	Date of measurement or inventory	Conductivity	Temperature °C	Use of water	Remarks
6S42E16ACD	96	45R	3,305				S	
6S42E23BCA	350	F	3,142	3- 6-74	1,970L	10.5	S	Q; yield, 2.1 gpm
6S42E23BDB	160	+12.0	3,140	3- 6-74	1,970L	10.5	S	Q; yield, 1 gpm
6S42E23CAB	570	+68.5	3,160	3- 6-74	1,420L	11.5	S	Q
6S42E27ABB	315	F	3,155	3- 6-74	2,360L	11.0	S	Q
6S42E29CAA	450	+9.4	3,180	3- 1-74	1,830L	10.0	S	Q; yield, 0.4 gpm

Table 12.—Chemical analyses of water from selected wells and springs in the Birney-Decker area

[Constituents in milligrams per liter, except as indicated. Depth of well: SP indicates spring. Remarks: 0.7 gpm indicates yield of well or spring in gallons per minute]

Location	Depth of well (feet)	Date of collection	Silica (SiO_2)	Iron (Fe), total	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Hydroxide (OH)	Alkalinity as CaCO3, total	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids, calculated sum of determined constituents	Hardness as $CaCO_3$: Carbonate	Hardness as $CaCO_3$: Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos/cm at 25°C)	pH	Temperature (°C)	Remarks
31N-48-10B8	930	12-19-73	8.6	0	0	4.2	1.7	550	2.5	1,120	53	0	1,100	1.2	180	3.0	0	1,960	18	0	60	2,250	8.8	13.5	
31N-47-10C8	172	3- -74	8.5	20	0	42	25	820	5.4	1,000	0	0	960	1,190	15	.7	5.8	3,080	200	0	25	3,460	8.3	10.5	
31N-47-15D0	295	-17-73	7.7	0	0	10	3.0	470	1.0	370	0	0	460	530	12	1.0	4.9	1,830	38	0	33	2,010	8.1	10.0	
31N-48-19DCB1	190	12-18-73	8.0	0	0	2.3	1.4	340	1.5	760	29	0	720	.9	65	2.9	.1	1,220	12	0	43	1,380	8.8	7.5	
31N-48-22BAA	200	1-12-74	11	0	30	75	35	330	10	910	11	0	930	880	4.8	.6	3.0	1,790	490	0	6.5	2,050	8.4	14.0	
31N-48-33BB	90	12-20-73	22	0	0	77	30	190	13	590	0	0	480	480	5.1	.7	72	1,335	0	0	3.7	1,550	7.8	8.5	
31N-48-34AA	150	12-21-73	8.6	0	0	2.8	1.0	330	1.2	760	0	0	650	1.2	32	2.2	.2	1,110	12	0	39	1,180	8.4	11.0	
31N-48-21B.S	900	12-18-73	8.0	0	0	3.0	.2	340	1.5	760	20	0	720	1.2	66	3.3	.4	1,250	8	0	33	1,380	8.5	12.5	
31N-48-33CBD	435	12-21-73	9.3	0	0	2.8	.9	360	1.6	820	36	0	740	4.9	.4	3.3	.4	1,270	16	0	50	1,470	8.5	12.5	
31N-48-4AD8	133	3- -74	3.0	0	0	15	16	1,000	9.4	1,010	36	0	900	1,400	8.2	.5	9.9	3,550	36	0	42	4,210	8.5	8.0	
31N-48-12ADD	SP	3- -74	17	0	0	52	140	140	9.7	570	0	0	15	500	5.0	.5	.1	1,340	0	0	2.4	1,720	8.0	9.0	
31N-48-14CBC	74	1-17-74	21	0	0	63	120	230	10	760	0	0	680	680	6.1	.4	5.0	1,690	460	210	3.5	1,940	8.0	8.0	
31N-48-15AA	130	1-17-74	24	0	13	85	190	300	10	830	0	0	730	820	8.8	.5	17	2,400	430	210	4.9	2,260	8.2	9.0	
31N-48-17DBD	85	1-17-74	18	0	30	58	150	370	24	760	0	0	620	1,000	6.1	.5	.7	2,460	420	260	5.4	2,720	8.1	7.1	
31N-48-19BAA	SP	1-18-74	12	0	0	100	54	1,000	10	1,120	0	0	920	1,700	11	.5	4.6	4,030	500	0	19	4,510	8.1	6.0	0.7 gpm
31N-48-19BA	90	1-14-74	25	0	420	140	140	730	24	1,200	0	0	820	2,100	11	.6	1.2	4,720	820	930	7.6	4,940	8.1	8.5	
31N-47-24AAB	SP	1-14-74	15	0	240	140	420	570	18	1,170	0	0	960	2,700	9.9	.2	7.7	5,260	980	1,400	6.0	5,040	7.8	9.0	0.1 gpm
31N-47-24DBD	50	1-22-74	30	40	270	90	140	360	23	810	0	0	530	1,000	9.1	.6	.8	2,290	500	290	5.8	2,590	8.7	10.0	
31N-48-17CCD	700	12-19-73	9.0	0	0	3.4	.4	430	1.8	930	0	0	760	5.8	85	2.9	0	1,470	8	0	46	1,570	8.1	14.0	Field pH, 8.4
31N-48-20ACA	185	12-19-73	13	0	0	91	160	320	8.4	920	0	0	750	780	11	.6	2.8	2,300	750	140	4.7	2,540	7.9	10.0	Field pH, 7.5
31N-48-27CCC	474	1-14-74	9.1	20	0	2.3	1.0	260	1.2	650	0	0	530	.5	23	2.0	.2	940	10	0	35	1,010	8.3	14.5	
31N-47-27DDB1	340	12-17-73	7.9	0	0	3.6	1.1	240	1.2	620	0	0	510	.3	30	1.9	0	900	11	0	32	9,880	8.1	11.0	Field pH, 8.5
31N-48-33DDB	10	1-14-74	12	0	0	710	150	55	5.0	430	0	0	350	650	5.3	.4	.2	1,850	110	440	1.3	1,790	8.0	9.0	0.5 gpm
31N-48-32CAD	17	3- -74	15	0	280	80	240	150	7.1	840	0	0	690	1,000	10	.5	.2	2,500	890	340	2.1	2,830	7.9	9.5	
31N-48-29DAB	17	1-16-74	19	90	240	60	110	340	21	920	0	0	760	1,300	8.4	.1	.1	3,720	760	2,300	4.3	3,720	7.7	7.5	1.0 gpm
31N-48-27CBB	19	1-16-74	19	0	0	270	420	340	20	880	0	0	720	1,100	11	.3	3.7	3,450	720	1,700	6.6	3,800	7.9	8.0	0.5 gpm
31N-48-21CCC	24	1-16-74	12	0	0	35	18	470	5.2	490	0	0	400	720	8.6	.5	5.2	1,760	160	0	18	2,270	7.9	8.0	
31N-48-14AAD	19	1-18-74	12	0	0	200	370	820	24	1,000	0	0	820	2,800	10	.5	33	5,290	820	1,200	8.0	5,290	7.7	7.5	0.8 gpm
31N-48-1ACB	850	12-18-73	8.0	90	0	7.4	1.3	380	3.0	420	0	0	340	480	14	1.0	5.3	1,420	32	0	29	1,740	8.3	7.0	Field pH, 8.3
31N-48-8BD	250	1-13-74	15	0	0	2.4	1.3	250	1.2	530	0	0	430	1.7	22	2.5	.6	930	12	0	32	1,010	8.3	13.0	
31N-47-8DAA	SP	1-13-74	19	40	0	130	140	58	4.9	550	0	0	450	430	5.9	.4	.1	1,460	370	350	.3	1,530	7.8	6.5	0.5 gpm
31N-47-9AD	SP	1-13-74	22	0	0	55	58	470	5.2	840	0	0	690	960	5.7	1.1	2.4	2,760	400	0	7.2	2,740	7.7	8.0	1.0 gpm
31N-48-17DAA	1,243	12-18-73	10	0	0	3.4	.9	540	2.9	1,310	53	0	1,190	2.5	140	.7	0	2,490	12	0	24	2,720	9.3	13.5	Field pH, 8.2
31N-48-16AB	SP	1-12-74	17	20	0	160	350	125	20	730	0	0	590	1,100	15	.5	.8	2,880	600	1,300	1.2	2,980	8.1	1.0	
31N-48-26AA	40	12-19-73	19	0	760	130	170	120	17	650	0	0	530	1,200	13	.5	2.5	2,990	530	510	4.4	2,950	7.7	10.5	Field pH, 7.5
31N-47-27ADD	SP	1-18-74	24	0	0	130	210	230	9.1	630	0	0	490	1,100	11	.4	.5	2,750	490	940	2.9	2,960	8.0	6.0	0.24 gpm
31N-47-30AD	SP	1-18-74	17	0	0	55	140	220	12	840	0	0	690	770	6.6	.4	.1	2,120	390	280	3.1	2,190	7.8	6.5	2.0 gpm
31N-48-21AB	SP	1-18-74	15	110	0	150	290	320	24	960	0	0	790	1,200	9.1	.5	2.8	2,870	710	800	3.8	2,850	8.0	7.5	
31N-48-20CDA1	18	1-14-74	20	0	15	130	240	470	45	990	0	0	810	1,500	10	.5	2.0	3,440	810	530	5.7	3,840	7.9	8.0	
31N-48-20BA		1-18-74	22	0	0	120	140	250	13	610	0	0	500	490	7.1	.5	.3	2,110	530	370	3.6	2,300	7.9	8.5	
31N-48-14BCC	30	1-18-74	17	0	0	93	150	290	12	720	0	0	590	930	6.3	.5	.9	2,260	590	330	4.1	2,360	8.0	8.5	
31N-48-17AA	SP	1-18-74	17	0	150	270	490	320	17	990	0	0	810	1,400	12	.3	4.9	4,470	820	1,800	2.9	4,300	7.3	2.0	0.3 gpm
31N-48-14BA		1-15-74	19	0	0	110	170	310	15	940	0	0	770	1,200	9.5	.4	4.3	2,970	570	940	3.1	2,850	8.0		Stream, 12.0 gpm
31N-47-11AD		10-11-73	13	30	35	130	72	190	12	550	0	0	490	700	5.7	.3	5.0	1,470	390	340	3.1	1,510	7.7	10.5	
31N-47-14AA1	33	10-11-73	24	20	25	40	45	75	4.9	290	0	0	240	350	4.4	.3	3.5	777	260	210	1.7	927	7.8	12.0	
31N-47-1CA	420	10-11-73	8.6	20	95	29	34	1,290	9.1	990	0	0	810	1,400	23	.5	18	4,140	170	0	46	4,900	8.0	13.5	
31N-47-1CB	1,115	2-11-74	12	7	10	120	34	1,100	12	1,140	0	0	940	1,800	7.2	.2	.4	3,600	660	0	22	3,710	8.2	11.0	
31N-47-1DA	74	10-24-73	15	0	0	120	69	210	9.3	940	0	0	770	1,100	8.0	.5	8.1	3,170	360	810	3.5	3,430	8.3	9.0	
31N-48-13AB	47	11-11-73	16	0	0	74	104	140	7.3	320	0	0	260	450	5.4	.5	5.8	1,310	260	360	2.4	1,350	7.8	9.5	
31N-48-24AAD	45	11-18-73	12	0	10	34	24	340	7.3	340	26	0	320	490	5.0	.6	9.9	1,280	190	0	12	1,530	8.6	9.0	
31N-48-10AB	18	12- 2-74	9.8	430	10	23	24	32	24	80	0	0	67	130	5.0	.1	3.0	270	83	49	.9	373	7.0	.5	
31N-47-10BC	42	2- 2-74	25	50	20	58	43	230	8.6	710	0	0	580	1,100	21	.2	1.8	3,300	390	2,000	6.3	3,340	7.8	8.5	
31N-47-11AA		2- 2-74	25	50	1,100	240	280	720	39	740	0	0	610	2,300	11	.4	7.1	4,100	640	1,100	5.6	5,270	7.8	8.0	
31N-47-11BB	10	2- 2-74	26	0	450	120	280	460	7.4	110	0	0	87	2,300	20	.1	1.3	3,410	67	1,500	5.6	3,540	6.0	8.5	
31N-47-14AA2	20	1-10-74	27	30	1,800	240	220	580	12	590	0	0	490	2,200	11	.4	2.9	3,810	470	1,100	3.5	4,060	7.6	7.5	
31N-47-AA3	13	2- 8-74	12	30	120	50	120	180	10	540	0	0	440	470	5.3	.5	1.0	1,500	430	160	2.7	1,660	7.9	3.0	3 gpm
31N-47-1A	11	2- 8-74	13	40	50	140	210	420	13	870	0	0	710	1,600	8.0	.4	7.5	3,810	400	520	7.4	4,120	7.9	6.0	
31N-47-1AD	18	2- 8-74	12	40	0	200	82	94	14	330	0	0	270	370	11	.4	6.5	1,280	270	0	1.4	1,750	7.7	.5	1.0 gpm
31N-47-1AAA	20	1-30-74	21	30	40	280	400	540	24	540	0	0	420	1,500	15	.5	.3	3,310	420	2,000	6.6	3,620	8.0		
31N-47-1DB	195	10-11-73	8.6	20	0	3.2	4	440	3.4	1,140	0	0	940	4.7	10	1.3	0	1,830	12	0	57	1,940	8.1	14.0	Field pH, 8.0
31N-47-12AA	168	10-24-73	9.4	0	10	18	22	710	3.8	1,580	31	0	1,470	280	35	.8	3.8	2,720	160	0	27	2,840	8.4	10.0	
31N-47-1CA	151	10-24-73	7.4	20	10	4.4	.7	450	3.6	0	18	0	1,150	.6	11.0	1.0	0	1,750	14	0	52	1,750	9.0	11.0	
31N-47-1CB	29	10-24-73	21	40	10	84	180	350	12	830	0	0	680	1,200	11	.6	7.5	2,450	520	480	6.9	2,620	7.9	10.5	
31N-47-1CA	47	10-30-73	11	20	90	120	170	230	6.0	520	0	0	430	1,200	5.5	.1	14	2,550	360	1,200	5.2	2,310	7.8	9.0	
31N-48-10AB		10-24-73	7.7	0	0	3.8	4.6	540	4.9	1,480	39	0	1,240	19	19	.9	8.6	2,310	32	0	49	2,250	8.8	10.0	
31N-48-10CC1	200	10-24-73	7.8	10	10	3.5	4.0	580	3.7	1,280	0	0	1,040	45	22	1.1	0	1,950	30	0	40	1,900	8.2	11.0	
31N-48-7ADA	70	10-30-73	13	20	20	240	320	650	9.6	1,220	0	0	1,000	2,700	14	0	3.3	4,310	820	1,500	8.7	4,340	7.7	10.5	
31N-48-7CDC1	18	10-29-73		10	130	230	190	110	4.3	750	0	0	590	1,100	12	.2	36	2,530	530	790	2.5	2,720	7.8	11.0	0.5 gpm
31N-48-8CDC2	227	10-29-73		0	20	9.8	4.7	660	4.5	1,230	0	0	1,020	.2	13	0	1.4	2,620	84	0	63	2,450	8.1	11.0	
31N-48-8CA	SP	1-24-74	15	2,800	410	280	340	1,400	14	5	0	0	4	1,100	35	.2	.9	3,775	0	2,100	16	5,400	5.3	9.5	0.2 gpm
31N-48-18CB	51	1-30-74	14	40	2,600	350	130	450	8.1	530	0	0	520	2,100	15	.3	8	4,240	520	1,500	4.4	4,340	7.7	8.0	
31N-47-30AB	153	1-29-74	9.0	20	0	30	10	530	8.2	1,060	0	0	1,040	290	3.8	1.3	8.4	1,940	220	0	32	2,230	8.1	9.0	
31N-47-1AAB	100	11-19-73	11	0	0	140	110	150	7.4	340	0	0	280	550	7.4	.2	2.5	1,420	280	550	3.3	1,830	8.0	10.0	
31N-47-1AAB	107	10-29-73	8.1	10	10	8.3	2.7	510	4.2	1,300	0	0	1,120	.1	17	1.0	8.7	1,920	32	0	39	1,910	8.2	12.0	